BUILDING SUPERVISION

NOTES ON GOOD BUILDING PRACTICE

by

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FOREWORD

The large number of duties connected with the supervision of building work cannot all be discussed comprehensively in the limited space available. It has, therefore, been thought desirable to confine the contents of this book to the essential purpose of supervision: namely, the production of efficient and durable buildings.

The matters considered are materials and workmanship, the protection of materials and works during construction, and other aspects affecting the durability of the building.

Although the design and specification of the building are usually outside the scope of the Supervisor's duties, his position is such that he can usually make helpful suggestions during construction, which most architects encourage him to do. It is hoped that these notes may be of assistance in this respect.

Only those forms of construction which are commonly employed at the present day are discussed. It is felt that no good purpose could be served by giving space to what at present can only be considered as luxury trades.

W. R. M. P.

May, 1948

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Part I

MATERIALS AND WORKMANSHIP

1. British Standards and Codes of Practice for Building

British Standards are available for most materials and manufactured articles that are used in building. They may contain requirements as to size, composition and performance, and frequently include particulars of tests necessary to determine whether the material or article attains the required standards.

The advantages of quoting standards are obvious, since the necessity for detailed descriptions of materials is avoided, as also is largely the need for site inspections and tests. Suppliers can be asked to guarantee that the materials delivered comply with the appropriate British Standard, and if subsequently any doubt exists concerning the quality of a particular delivery, the tests described in the specification can be made.

The Codes of Practice for Building have not yet been published, but their preparation is in an advanced stage. Their function is to indicate the best building practice for all trades in the light of present-day scientific and practical experience, and, in addition, to set up standards of functional performance for buildings. The issue of these codes should mark a turning-point in the history of building, for this is the first attempt to collect comprehensive data on good building practice and produce them in a concise form.

Both forms of publication should be of great value to those engaged in supervising building work.

In the following notes it has been considered necessary to draw attention only to the more important points affecting the quality of the finished building. No attempt is made to provide specifications of materials and workmanship, or to deal with the routine duties of a clerk of the works.

2. Nature of the Sub-soil

The difficulty and expense involved in making good defects due

to settlement are sufficient reason for ensuring that the foundations of a building are designed on a sound basis. This entails a careful study of the nature of the sub-soil in order to determine the depths and widths necessary for the support of the structure or whether special methods of construction are necessary.

Much useful information can usually be obtained locally concerning the composition of the sub-soil of a particular site, and the experience of local authorities is of great value in this respect. It is, however, advisable to check the information received from local sources by excavating trial-holes in various parts of the site.

In some districts the nature of the sub-soil may vary greatly within short distances, and it may then be necessary to increase considerably the number of trial-holes. This applies particularly to sites on "made up" sub-soils.

Some natural sub-soils contain gypsum, which fact will almost certainly be known locally. If, in addition, the site is wet, it will be necessary to take special precautions with concrete and cement mortars used below the ground level. On "made up" sites, gypsum and other deleterious impurities may be present as a result of the dumping of builders' rubbish, furnace and factory waste, etc. The measures which should be taken in such instances are described later.

Apart from sites with sub-soils containing injurious substances, those with clay or wet sub-soils need particular care.

(1) Clay Sub-soils

Clay has the property common to most materials capable of absorbing moisture, that of expanding when wet and shrinking when dry. If, therefore, foundations are laid on wet clay and subsequent to the erection of the building the clay becomes dry, the whole structure tends to settle. This would not be very serious if the settlement were uniform and not excessive, but unfortunately such movements are usually far from regular, and may therefore cause serious cracks in a building.

Clay near the surface of the ground varies in moisture content, and consequently in volume, according to the season, but at a depth of about 3 ft. 6 in. movements are not serious. Foundations on clay, should therefore be taken down to at least this depth, irrespective of whether a firm bottom can be obtained at a less

depth or not. Making the foundations wider instead of deeper is, in such circumstances, useless.

Reinforced raft foundations, if properly designed to ensure even settlement, can be satisfactory on clay soils, but it is advisable to project the raft to the extent of about 3 ft. beyond the external walls, to reduce the variation in moisture content of the clay under the load-bearing walls.

(2) Wet Sub-soils

Wet sites may also be a source of settlements. Those which can be, should be drained before the building is commenced and the foundations carried down to a firm bottom. With sites which are permanently wet and where drainage is impracticable, raft or even pile foundations may become necessary. Their design is then a matter for specialists.

(3) Subsidence

In mining districts settlements due to subsidence are of frequent occurrence and often sufficiently serious to endanger the safety of the structure.

In such instances the design should be by specialists experienced in this class of work. It may be necessary to use fully framed construction on a specially designed raft. Obviously, a mere increase in the depth of the foundations is useless.

(4) Proximity of Trees

Quickly-growing trees, such as poplars, should not be planted near buildings. These require a great deal of moisture for growth and may therefore cause settlement by draining water from a clay sub-soil.

(5) Sloping Clay Sites

If buildings are erected on a sloping site and the sub-soil contains a layer of clay, there is a risk that damage will occur as a result of the upper layers of soil and the building sliding downwards on the clay.

Whether this risk is serious or not can usually be judged by an inspection of buildings, walls or even telegraph-poles in the vicinity. All will tend to lean in the direction of any movement of the soil over the clay.

(6) Unequal Loading

Besides settlements caused by differential movements of the sub-soil, similar trouble can arise when uniform soil is irregularly loaded. Common examples of this are when one-storey buildings, such as "lean-to" structures, bay windows or heavy chimney-stacks are connected to the main building and no allowance is made in the foundation design for the difference in pressure on the soil.

Where the variation in loading is great, for instance in the case of factory chimneys adjoining one-storey boiler houses, the structures should not be connected to the main building. Where differences in pressure are relatively small, differential settlement can be reduced or prevented by carrying down the foundations of the lighter part of the structure to the same depth as that of the main building and reinforcing the foundations where the two buildings connect.

3. Concrete Foundations and Over-site Concrete

(1) Materials

Cement. There are British Standards for all types of cement, and the manufacturers will supply material under a guarantee that it complies with the specification. This eliminates site testing and ensures uniformity of quality.

Foundation work can usually be carried out with ordinary Portland cement or blast-furnace Portland cement, but when speedy building is necessary, or in cold weather, rapid-hardening cement and, in special circumstances, high-alumina cement can be used.

High-alumina Cement is especially useful for stanchion foundations when quick erection of steel frames is essential, but concrete made with this material is liable to become excessively hot, and, in consequence, lose its moisture before the setting process is complete. This makes it necessary to keep the concrete wet for about twelve hours after placing.

Aggregates. The properties necessary for concrete aggregates, both coarse and fine, are covered by British Standards.

In foundations, and especially where site conditions are damp, it is essential that aggregates having a deleterious effect upon cement should be excluded. Such materials include soft, under-burnt brick rubble, old brick or stone rubble with adherent plaster or other contamination, e.g. soot, acids, etc., from chimney flues, and furnace ash or clinker unless previously tested and found

suitable for the purpose. Such materials may cause expansion and disintegration of the concrete, due to chemical reaction between the aggregate and the cement.

All-in aggregate usually consists of a natural mixture of coarse and fine material, to which, in some cases, extra sand has to be added.

It may sometimes, therefore, consist of a load of coarse aggregate with a superimposed proportion of sand. Even if the proportions are correct, it is obvious that unless precautions are taken, successive batches of concrete cannot be uniformly graded. In such circumstances it would seem that the only way of assuring uniformity is, in the first place to make sure that the proportions of coarse and fine material are correct at their source, and carefully to remix every batch as it arrives.

Hardcore. It is important to exclude the use of deleterious materials from hardcore fillings under floors, since water rising through the hardcore may convey soluble salts present in the material to the concrete and cause expansion, resulting in the buckling of oversite concrete, distortion of the external walls, or both types of trouble.

(2) Workmanship

Concrete. The density and strength of concrete is dependent upon the richness of the mix, the grading of the aggregates, the amount of water used and the amount of care exercised in placing and consolidating the mixed material.

The correct grading of the aggregates (coarse and fine) can be attained by purchasing under guarantee from the suppliers that they comply with the requirements of the relevant British Standard.

The water content of the mix cannot, in practice, be arbitrarily settled in terms of weight or volume, since the aggregate, as stored on the site, more especially the fine aggregate, may either be dry or contain a high proportion of water. Experience alone will decide whether a mix is of the correct consistency or not. It can, nevertheless, be said that concrete should be placed in the driest state that will permit satisfactory consolidation. Concrete consolidated by vibration requires less water than when it is consolidated by other methods.

Concrete Foundations. In the case of mass foundations, ramming is usually sufficient for compaction, but in the case of concrete in deep trenches or with reinforced concrete foundations

cast in formwork, rodding is to be preferred. Vibration is seldom used except on large jobs.

Over-site Concrete. The purposes of over-site concrete are the prevention of the growth of vegetation under the floor and the reduction of the rise of moisture from the soil. The first is readily attained provided the top soil containing the roots and seeds of vegetation is removed before the concrete is laid.

It has to be realised, however, that no concrete is entirely impervious to moisture even in liquid form, and that even the densest concrete can permit some penetration of water vapour. When placed upon satisfactory hardcore, e.g. dense stone or brick rubble laid in position without fine material, concrete should not permit the rise of liquid moisture, but there is still the risk that vapour may penetrate.

Where hollow floor construction is used, the access of water vapour to the under-floor space is of little consequence provided ventilation is adequate. However, with solid floors laid directly on the soil or on hardcore, it is necessary in most instances to prevent the rise of moisture by providing a continuous vapour-proof membrane in the body of the concrete raft or immediately above the surface. The matter is discussed later under "Floor Finishes."

Concrete in Soils containing Sulphates, etc. On sites where the sub-soil contains gypsum or the site is made up of waste materials containing sulphates or other matter deleterious to concrete, the latter should be as dense as possible to prevent the conveyance of injurious substances by soil water into the body of the concrete.

Also, wherever possible, the surface of the concrete exposed to the soil back filling should be heavily coated with bitumen. Such precautions are especially necessary on wet sites.

Where contamination is severe and much water is present it may be necessary to use concrete of special composition, but this is a matter upon which expert advice should be obtained.

Similar precautions should, of course, be taken in the case of concrete pipes, drainage joints and buried cement mortar or concrete. Brickwork or other masonry built in cement or cement-lime mortar requires careful protection against sulphates.

4. Basements

The conditions under which walls and floors below ground-level are exposed are very different from those occurring in the

superstructure. Both may have to resist the penetration of water under pressure, and furthermore their outside faces may remain permanently damp.

(1) Asphalt Tanking

In modern buildings it has become common practice, even on relatively dry sites, to protect all underground rooms by a continuous asphalt tanking. By this means the basement can be made as dry as rooms in the superstructure, and similar materials can be used throughout the building.

Asphalt, although in appearance rock-like, has the properties of a highly viscous liquid. It will flow in the course of time, especially under warm conditions, and so requires positive restraint against this tendency. On the other hand, if, when hard, it is subjected to impact or to forces causing it to bend, its brittleness may result in fracture.

In tanking a basement, therefore, it is advisable to support the asphalt to prevent flow and to protect it against impact and pressure. Both results can be achieved by inserting the asphalt layer between two leaves of masonry or concrete.

With this construction it must be remembered that water pressure will act horizontally on the basement walls and almost inevitably water will penetrate the outer leaf. It must be assumed in the design, therefore, that the full water pressure will be exerted on the asphalt. The usual method of construction is to apply asphalt externally to the main structural wall and thereafter to build closely against it a protective wall which may be relatively thin. Soil by itself is not sufficient to prevent the downward flow of the asphalt, which in the absence of more positive support will result in time in the material cracking, thus providing a source of moisture penetration.

Floors are subject to water pressure acting vertically upwards, and must be sufficiently strong to resist the pressure. It is common practice to lay the asphalt between two reinforced concrete rafts, both designed to resist upward pressure, but for the sake of economy one layer is sometimes unreinforced. It is necessary in such circumstances to reinforce the upper layer.

The utmost care is required in applying the asphalt and especially in the jointing of the wall and floor membranes, for the slightest leakage will result in a gradual percolation of moisture, and a head of water may be built up between the internal leaves

of the structural walls or those of the floors and the asphalt damp-proof course. This may not only cause dampness in the walls and floor but actual flooding of the basement.

When basements are built in clay soils the made-up ground around the external walls may act as a reservoir for surface water. Since hydrostatic pressure depends solely upon the head of water, the resulting conditions will be similar to those which prevail when a basement is built in a waterlogged soil, The same precautions against water penetration therefore becomes necessary, and the full hydrostatic head must be assumed in design.

Provided the tanking is efficient and adequate ventilation is provided, no special precautions against the effects of dampness need be taken with regard to materials and construction inside the tanking: the work can be similar to that used in the superstructure. However, good-quality brick built in cement mortar should be used for the external protective walls and high-grade concrete under the asphalt floor membrane.

(2) Reinforced Concrete Tanking

Possibly the only satisfactory alternative to a tanked basement is one built in reinforced concrete with the reinforcement carefully designed to prevent shrinkage cracking and constructed of truly dense concrete. This form of construction is of obvious advantage in deep basements where lateral soil pressures may be high. However, asphalt tanking in addition would be a wise precaution on wet sites, since water under high pressure may to some extent penetrate even dense concrete.

(3) Effect of Oils and Petrol on Tanking

On rare occasions oil or petrol may find its way to the sub-soil. Sites adjoining garages or car parks may be affected in this way. Asphalt is softened by both and the usefulness of a tanking may be destroyed by their presence in the sub-soil. Reinforced concrete construction is to be preferred in such circumstances.

5. Structural Frames

Structural frames may be of steel, of other metals or of concrete, cast-in-situ or pre-cast. In all instances the design and erection of frames is usually entrusted to specialist firms.

Except in a general way, therefore, the supervision of such work

falls outside the scope of those responsible for the supervision of the main building.

The chief points of interest to the general supervisor are the degree of accuracy of the completed frame, the rigidity of the joints and, in the case of metal frames, especially of steel frames, the protection provided against corrosion.

(1) Accuracy of Frames

The tendency at the present time is to clad structural frames for houses with factory-made units constructed on jigs to standard sizes. With such construction it is essential that the frames should reach at least the same degree of precision as the units and provide the necessary tolerances. The supervisor should check all measurements affecting the fitment of the units. It is easier to alter the frame than several hundred units.

(2) Protection against Corrosion

With all metal frames proper protection against corrosion is important, and especially so in the case of light-gauge pressed-steel frames, since a high proportion of the strength can be lost with even a small amount of corrosion. It should be ascertained that the method of protection adopted is in accordance with the latest recommendations from authoritative sources, e.g. British Standards.

It is advisable to apply a finishing coat of paint to all structural steelwork after erection, but damage to the factory-applied protection sustained during transport and erection should be made good before the final painting. Bolts, nuts, etc., should receive a preparatory treatment before the final paint coat is applied.

(3) Bolted Steelwork Connexions

The main items of construction to be watched during the erection of steelwork are those upon which the rigidity of the joints depend.

Care should be taken to see that no bolts are omitted; that washers are used where required to keep the bolt thread clear of the hole; that all nuts are properly tightened and that, after tightening, at least one thread of the bolt projects through the nut.

It is also important to see that bolt holes are properly finished to ensure that projecting metal does not prevent an even and

close contact between steel members or between them and the bolts, nuts or washers.

Where tapered washers are necessary the connexions should be examined to ensure that an even bearing and tight joint is formed. Unless the washers are carefully fixed the bolts may subsequently work loose. Where there is likely to be excessive vibration all bolts should be treated after fixing, usually by burring the threads, to prevent loosening of the nuts.

In general, steel encased in concrete should be well cleaned, but not painted, but where steel connexions are encased, the adjoining surfaces should be bedded in a suitable paint, e.g. red lead paint, to prevent corrosion.

(4) Concrete Frames

With cast-in-situ frames it is important to ensure that the concrete is made of the materials specified; that it is not too wet when placed; and that the placing and consolidation are carefully carried out. It is most important to see that the reinforcement is correctly placed and has sufficient cover to protect it from corrosion. This entails constant supervision of manufacture.

Frames constructed from pre-cast concrete units should be carefully examined for defects before erection. Rust stains usually indicate that the reinforcement has been placed too near the surface. Cracked or badly chipped members should be rejected. The use of wooden moulds usually results in deformation in the various frame members. Slight deformation may not be important but in some instances more serious defects of this nature may affect the strength of the structure. For example, the incorporation of primary floor or roof beams which are out of true into a building may result in a reduction of bearing for some of the secondary beams.

This type of defect is of the utmost importance when factory-made units are used in the construction of floors and roofs.

6. Load-bearing Walls

(1) Solid Brickwork

Materials

Brick. Brick is manufactured of burnt clay, sand-lime or concrete, and all types may vary considerably in the properties which determine their suitability for a particular purpose.

That all bricks should "ring" when struck and that none which

absorbs more than a small amount of water is suitable for use, is not in accordance with experience. For instance, it is common knowledge that certain types of brick which have proved durable in buildings for many centuries are relatively soft and are more absorbent than many less durable kinds.

There are British Standards for all types of brick. That dealing with clay brick is concerned with size only. Where doubt exists as to the quality of clay brick, tests can be made by which the future behaviour of the brick can be assessed with some degree of accuracy. Many manufacturers can provide test data on their products. Sand-lime and concrete brick should comply with the requirements of the appropriate British Standards.

Cement. Cement for brickwork mortar can be normal British Portland cement, British blast-furnace Portland cement, rapid-hardening British Portland cement and, in very exceptional cases, high-alumina cement.

There are British Standards for all types.

Limes. Suitable limes for brickwork mortar are hydraulic (blue lias), moderately hydraulic (greystone), magnesian and high-calcium (white or fat limes). The last is not commonly used for brickwork except in combination with normal Portland cement. It is rarely suitable for the purpose without a cement admixture.

All except magnesian lime can be purchased in bags in a slaked condition (hydrated) and so ready for use in mortar. Hydraulic lime is also available in bags as a ground quicklime, but it is important that this material should not be confused with powdered *hydrated* hydraulic lime, since the former must be slaked before use in accordance with the instructions of the manufacturers.

Lump and ground hydraulic quicklimes are slaked by wetting and covering with sand to conserve the heat generated by the slaking process. This operation should be entrusted only to those experienced in the use of the particular type of lime, or its hydraulic properties may be reduced. Particles of unslaked lime may also be incorporated in the mortar and cause unsoundness. This will result in local "blowing," or general expansion of the mortar joints, with disastrous results to the brickwork.

Magnesian limes also require careful slaking, or similar results may follow.

Lump greystone and white limes are usually slaked by being run to lime putty and subsequently matured before use to avoid unsoundness.

The respective British Standards and Codes of Practice give recommendations for the slaking of all types of lime, and these should be carefully followed.

Sand. Bricklayers usually prefer mortars made with what is termed a "soft" sand. The expression "soft" merely means that the sand produces a mortar which is more plastic and more easily applied than when "sharp" or harsh sands are used.

"Softness" in natural sands is usually due to the presence of a high proportion of loam or clay, which may be the cause of high drying shrinkage and loss of strength. However, the demand for workability in a mortar is not unreasonable, since by using a plastic mortar, joints are more easily filled and the speed of bricklaying is increased. Plastic mortars can be obtained with a well-graded clean sand by the addition of a proportion of lime to the normal cement and sand mix. This obviates the disadvantages associated with straight cement mortars made with dirty sands.

In districts near the coast sands may contain salts derived from sea-water. Although the presence of sea salts may not appreciably affect the setting time and ultimate strength of mortar, it is essential to avoid the use of such sands for work above the damp-proof course. Certain sea salts have the property of attracting and absorbing moisture and their inclusion in a mortar mix may lead to the permanent dampness of walls in which they are used.

Mortar. The efficiency and durability of brickwork largely depend upon the type of mortar used. If brickwork is required to carry heavy loads, a strong dense brick should be used, and on the principle that a chain is only as strong as its weakest link, an equally dense mortar is necessary. It should, however, be pointed out that the use of mortar of greater density than the bricks is of no appreciable benefit to strength and may be a source of trouble in other ways.

When the primary function of brickwork is to resist moisture penetration, the choice of mortar is of no less importance. On the face of it, it would appear that a dense mortar is necessary, but in practice it has been found that such mortars may give rise to serious trouble. Penetration of moisture usually occurs through cracks between the brick and vertical mortar joints rather than through the brick or the mortar. Mixes rich in cement have a high drying shrinkage, and when they are used the cracks in the joints may be larger though more widely distributed than with weaker mortars, e.g. cement : lime or hydraulic lime mortar.

Cracks in an impervious material are especially vulnerable to penetration caused by capillary force and wind pressure. With less dense mortars, which are more pervious, the shrinkage is less, and the cracks are more evenly distributed, finer and spaced more closely together. The result is that small quantities of water entering the cracks are absorbed by the mortar or brick and spread more or less evenly over the wall face, whence, under drying conditions, the water tends to evaporate.

The use of impervious brickwork facing, when the backing is constructed of more porous brick, aggravates dampness because, during rain, a continuous flow of water occurs over the face of the wall, and moisture entering the shrinkage cracks is absorbed by the backing.

Evaporation in dry weather is prevented by the dense facing.

It is of course possible with the highest class of workmanship to build solid walls in dense mortar and brick and be reasonably sure of weathertightness, but this class of work is expensive and it is difficult to obtain the necessary high standard of workmanship.

In general, the strength and density of the set mortar should approach but not exceed that of the brick. This includes the material used for pointing when this operation is considered to be necessary. Pointing as the work proceeds, with the same mortar used for bedding and jointing, produces the most satisfactory and durable brickwork.

In this connexion it may be noted that when dense mortar is used with brick liable to efflorescence the salts tend to crystallise on or in the brick rather than on or in the mortar. With some types of brick this may cause disintegration. It is true that the crystal formation may disintegrate mortars, but pointing is more easily replaced than brick.

The mortar for use with sand-lime and concrete brick requires special consideration. Both types have a far higher moisture movement than clay brick, so that the tendency for cracking at the mortar joints is increased. If dense cement mortar, which adheres strongly to the brick, is used, shrinkage may even result in vertical cracks running through joints and brick alike. It is essential with these types to use a mortar less dense than the brick, e.g. cement-lime, hydraulic lime, etc. Straight cement mixes are unsuitable.

(2) Cavity Walls in Brickwork

A properly designed and constructed cavity wall should be completely resistant to moisture penetration, but on the other hand poor design and workmanship may result in the wall being less resistant than a solid one.

Constructional details are dealt with later, but here emphasis is placed on the necessity of keeping the wall ties, cavity gutters and cavity below the damp-proof course free of rubbish and mortar droppings; of ensuring the correct placing and formation of the cavity gutters and vertical damp-proof courses between the two leaves of the wall; and of building the external leaf of brick without fissures and cracks and with fully flushed joints.

All of these points must be carefully watched or internal dampness will result.

Wall Ties. A British Standard for wall ties is available and should be followed.

Ventilation of Cavities. There are two schools of thought with regard to the ventilation of the cavity. Those who prefer to ventilate consider that condensation in the cavity or the penetration of rain through the outer leaf may, in the absence of ventilation, lead to dry-rot attack on built-in timbers; while others rightly claim that ventilation reduces the thermal insulation of the wall, and also consider the risk of dry-rot attack to be not serious.

Dry-rot can only develop when the moisture in timber reaches 20 per cent. of its dry weight. This is unlikely in the case of floor joists or other timber members built into the internal leaf of a cavity wall, for although such members may absorb a little moisture, evaporation can take place on the rest of the timber surfaces inside the building, and it is therefore improbable that the moisture content of the wood will approach the danger-point.

On the whole, the advantages are on the side of a sealed cavity. Should a wall of this type, however, be built in wet weather and immediately be coated externally and internally with dense cement mortar, the two leaves may remain damp for a long period. This will reduce the overall thermal insulation of the wall and probably give rise to condensation inside the building.

In such circumstances it might be possible to provide ventilation for (say) a year to assist in drying the brickwork. Thereafter the vents should be sealed.

Cutting away Cavity Brickwork. One of the difficulties associated with cavity walls having thin inside leaves is that cutting

away or plugging may result in damage. This is especially the case when the inner leaf is built of unduly weak mortar.

The remedy is to reduce cutting away and plugging to a minimum by leaving holes for pipes; building in brackets; providing the necessary fixing bricks, etc., and to use mortar sufficiently strong (though not necessarily a dense cement mortar) for its purpose.

(3) Filled Cavity Wall Construction

The practice of filling the cavity of an external wall with concrete is to be deprecated. The filling is a difficult and costly operation, and a wall of this construction is more liable to damp penetration than a normal cavity wall. Furthermore, it provides less resistance to heat loss and is therefore more liable to condensation.

Concrete used in this way cannot be properly consolidated, and fissures and holes through which moisture can penetrate will almost certainly occur. In addition, it is to be expected that the natural drying shrinkage of the concrete will result in cracks.

If a cavity wall is properly constructed no moisture penetration is to be expected and the concrete filling is, therefore, unnecessary even if it can be made effective.

(4) Masonry Walls

Natural Stone

At the present time stone masonry is too expensive for general building work and it is doubtful whether it will ever again be used to the extent it has been in past years. A few points of interest are, however, dealt with.

Natural stone may disintegrate—as a result of frost action, by the crystallisation of salts in the pores or by erosion caused by rain or wind-blown sand.

In most circumstances the supervisor has little to do with the choice of stone and cannot, therefore, be held responsible for any general lack of durability. However, he may be able to avoid local troubles.

Frost Effect on Stone. Frost has its greatest effect upon laminated stone, especially when the laminations are divided by soft, porous material. Poor-quality limestones and sandstones may be of this type. Trouble arises when the soft material between the stone layers becomes saturated by rain and is subsequently

exposed to frost. The expansion consequent upon the freezing of water in the soft material tends to push the layers apart and disintegrate the stone.

The stones most likely to be affected in this way are readily detected and should be rejected, especially if they are intended for positions exposed to severe exposure, e.g. cornices or other projecting members, quoins, etc. In fully protected positions, e.g. immediately under deep cornices, such stones may last a reasonably long time.

No stone, and more especially laminated stone, should be built otherwise than on its natural bed. Face-bedded stones are particularly liable to disintegration by frost.

Effects of Sulphates on Stone. Porous stones may absorb moisture containing sulphate salts from brickwork used as a backing or from ashes, clinker or contaminated bricks used as a filling under floors, etc. At the surfaces where evaporation of the moisture takes place the salts may crystallise beneath the surface in the pores of the stone and consequent expansion may cause disintegration.

Careful attention to constructional details, more especially damp-proof courses and the use of suitable bricks for backing, will eliminate the risk of damage from the first cause. Clean stone filling only should be used behind masonry walls.

In industrial districts the atmosphere may contain a relatively high proportion of acid gas and soot containing sulphates. Troubles similar to those described above may therefore occur. Limestones are chiefly affected, because the acids in the atmosphere combine with constituents of the stone to form sulphates. However, sandstone units, e.g. sills built into a wall mainly composed of limestone, may absorb a solution of sulphate from the limestone which has been attacked by acid and crystallisation may cause disintegration of the sandstone.

Limestone buildings should be periodically cleaned with water to remove soot and harmful substances, and so reduce the rate of decay. Sandstones used in limestone walls should be separated from the limestone by a damp-proof membrane, e.g. bitumen, and should, where possible, be protected by projecting members to prevent the absorption of water flowing from the limestone surfaces.

Cement Staining of Limestones. Certain limestones, especially the oolites, e.g. Portland and Bath stone, can be stained by

water contaminated by cement. This is caused by chemical reaction between constituents of the cement and organic matter in the stone.

Where the backing of a wall of such stone is built in cement mortar or when cast-in-situ floors, frame, lintels, etc., form part of the structure, the back of the stone should be protected with bitumen or cavity construction should be used to prevent contact between the stone and cement.

Cast Stone Masonry

Cast stone masonry consists of precast concrete units presenting a stone-like appearance and built in a somewhat similar way to natural stone masonry of the type used for monumental buildings.

In common with other concrete units, those of precast stone have a relatively high drying shrinkage, and in order to reduce the risk of shrinkage cracking, the mortar joints should be wider than those used for natural stone and composed of rather weak material. Cement-lime mortar is suitable for this class of work.

Cast stone units can be purchased under guarantee that they comply with the relative British Standard, the provisions of which, among other things, ensure proper curing and, therefore, a reduction in the drying shrinkage.

(5) Cement Concrete Walls—Load-bearing

Cast-in-situ Walls. Dense Concrete. The existing Code of Practice for reinforced concrete deals exhaustively with monolithic reinforced concrete. The Code should be followed and it is desirable that a firm specialising in this class of work should be employed in reinforced concrete construction.

General Supervision. General supervision of reinforced concrete work should include careful examination of the mixing of the concrete and placing of the reinforcement. It is also necessary to ensure that the aggregate is of good quality and kept clean up to the time of mixing. Much trouble in subsequent operations can be caused by formwork being badly erected. When this occurs, floors, roofs and walls may be out of true which may entail extra plasterers' labour and material, with an added risk of shrinkage, cracking, or even the necessity of cutting away projecting portions of the concrete.

Particular care should be taken to see that an excess of water is not used in reinforced concrete mixes for the purpose of facilitating placing and obviating the need for proper consolidation. An

excess of water results in higher drying shrinkage and consequently a greater risk of cracking.

Another point for attention is that concrete should not be dropped from a greater height than is necessary, since segregation of the mix may occur and result in variability in density, an increased tendency to cracking and local loss in strength.

The difficulty experienced in cutting chases and holes in dense concrete renders it essential to reduce such work to a minimum. This can be done by careful advance planning and by the use of cast-in plugs, wood fillets, etc.

Key for Plastering on Concrete Surfaces. If it is intended to plaster the internal or external surfaces of concrete walls, provision must be made to obtain a good key. The hacking of dense concrete surfaces for this purpose is costly and not always effective. In late years "retarders" have been used. They consist of liquids or "creams" which, when applied to formwork, prevent the setting of cement in contact with them, the result being that after wire brushing the aggregate is exposed in part and a good key is provided for applied plastering.

Another effective method of forming a mechanical key on smooth concrete surfaces is to apply a coat of "spatterdash". This consists of throwing or "dashing" on to the concrete a mixture of cement and sand which forms rough "blobs" on the surface. The mixture should consist of two parts of course clean sand and one part of cement mixed to a rather wet consistency. It should be constantly stirred while being used and thrown on forcibly by means of a small flat tool—the metal part of a child's steel sand spade is well adapted for the purpose. It is only by practice that the treatment can be applied successfully. The finished work should consist of small "pimples" of material closely and evenly spaced. It is advisable to keep the "spatterdash" coat moist for a day or two after application.

Cover to Reinforcement. Reinforcement or other embedded ferrous metal should be kept at least half an inch away from the surface of concrete, otherwise rusting will occur in the course of time and will result in spalling and cracking of the concrete. This is of the utmost importance in small members, such as door jambs, window-sills and architraves, etc.

"*No-fines*" *Cast-in-situ Concrete*

In recent years "no-fines" concrete has been used in the construction of walls. The concrete is essentially medium-sized

($\frac{3}{4}$ to $\frac{3}{8}$ in.) aggregate, with no addition of sand or fine materials, bonded with neat cement grout to form a cellular or honeycomb structure. Heavy- or lightweight aggregates can be used, the latter providing useful thermal insulation.

The mixing and placing of the material presents certain problems and the effect of its special properties must be taken into account in design and construction. Two points in workmanship need particular attention.

Consistence of "No-fines" Concrete Mixes. The essential feature of "no-fines" concrete is its cellular structure, which prevents the rise or penetration of moisture by capillary action. If the mix is too wet the cement grout will flow downwards and fill up the cells, which then cease to be effective in preventing capillary attraction. The consistence of the mix, which is critical, can only be obtained by experience. The aggregate may be dry or contain moisture to a lesser or greater degree, and it is therefore impracticable to measure the mixing water.

All particles of aggregate should be completely covered with a paste of cement grout of cream-like consistence. If drier, general loss of strength will occur; if wetter the base of the lift will be solid and the top will lack cement. Some authorities prefer to mix the concrete with an excess of water and to drain it before placing.

Placing "No-fines" Concrete. "No-fines" concrete should be poured evenly all around the building and carefully rodded without ramming or any other form of compaction. Over-compaction will result in an undesirable degree of density in some places and in others the formation of local weak pockets of concrete. The type of trouble known as "pyramiding" is, as the name suggests, caused by placing the concrete at the slope instead of in level layers. With unsuitable forms of shuttering, "pyramiding" frequently occurs under sills, etc.

Since "no-fines" concrete of correct consistence does not flow like wet concrete, but pours like dry aggregate, the use of formwork, which provides access to such parts of the wall to permit hand compaction, would appear to be desirable for the production of good walling in this material.

Key for Plastering to "No-fines" Concrete. The key provided for plastering and external rendering on "no-fines" walls is excellent. No special means of providing a key is therefore needed, as is necessary in the case of normal dense concrete.

Concrete made with Lightweight Aggregates

Lightweight aggregates can be used in the construction of cast-in-situ concrete walls. They have the advantage that, when the concrete is properly made, the thermal insulation value is high.

Suitable clinker, foamed slag, expanded clay and pumice are all satisfactory aggregates, but the supply of the latter under present conditions presents difficulties.

Unsoundness of Clinker and Ash Aggregates. The chief danger in using clinker or ash concrete is that the aggregate may be unsound. That is to say, that it may contain particles which, after incorporation in the concrete and being subsequently exposed to damp conditions, may expand, the result being gross general expansion of the concrete, causing serious cracking or local "blowing." Further wetting of the concrete caused by the cracking may then result in further expansion and the stability of the wall may be endangered. Soundness can only be ensured by using material complying with the British Standard.

Compaction of Lightweight Concrete. The main object of using lightweight aggregates in concrete is to increase the thermal insulation: the degree of insulation provided being dependent upon the low density of the concrete. Only the minimum amount of compaction to obtain uniform work is therefore required. The concrete should not be heavily rammed.

Weather Protection of Lightweight Concrete. The resistance of lightweight concrete to moisture penetration is not high and a waterproofing external surface treatment is therefore required.

This matter is dealt with under "External Wall Finishes."

Strength of Lightweight Concrete. All lightweight concretes have lower tensile and compressive strengths than normal concrete and this should be considered in design. Load-bearing walls need to be thicker than when normal concrete is used, and point loads need to be distributed over greater areas. Owing to its weak structure the bond between lightweight concrete and reinforcement is poor and if it is to be used for lintels, beams, etc., careful design becomes necessary.

Walls of Precast Units

Many types of concrete wall construction have in late years been put forward as substitutes for conventional brick and stone masonry. These range from plain block walling, usually in cavity

construction, to systems in which large and often complicated units are used.

Concrete Block Masonry in Cavity Construction. There is little difficulty in building an efficient cavity wall in simple concrete block masonry. The same principles as govern brick cavity construction apply, though the increased height of the building units tends to complicate the design of constructional details.

Concrete blocks are often manufactured on the site with either power or hand machines. When this is done there should be careful supervision of the manufacture to ensure that the blocks when used are equal to the quality required by the appropriate British Standard. In rushed jobs there will always be a tendency to mix improperly; to be careless in regard to the water content of the mix; to use any available aggregate when delivery of the specified material is for any reason delayed; and, worst of all, to shorten the time of curing. Lack of shed accommodation may also result in open-air storage of blocks, with the risk that they may be built into the walls in a thoroughly wet condition or become damaged by frost while they are still "green."

Improperly cured or wet blocks, especially in the case of those made with lightweight aggregate, will have a high drying shrinkage and inevitably cause severe cracking.

To reduce the risk of shrinkage cracks it is essential, with this type of masonry, that the mortar used should be weaker than the blocks. A cement-lime mortar (1 : 2 : 9 cement : lime : sand) is a useful mix for average blocks.

Special blocks for quoins and other fitments can easily be made on the site. Even when the plain blocks are purchased, it is always preferable to use "specials" rather than to cut and fit ordinary blocks for various purposes. A stronger and more workmanlike job is thereby obtained.

With cavity block masonry it is more difficult to ensure clean wall ties and cavity gutters than with brickwork, but this should be no excuse for bad workmanship. When made by the semi-dry process, concrete blocks are often rather porous, and in addition the inevitable cracks, though perhaps small, caused by drying shrinkage will permit a certain amount of penetration through the joints of the outer leaf. It is therefore essential to ensure strict cleanliness of the cavities in concrete block masonry or the inner leaf may become damp.

Solid Walls in Concrete Block Masonry. Concrete block

masonry may also be constructed in solid or cored (hollow) blocks the full thickness of the wall. The same precautions must be taken with regard to curing and the composition of the mortar as with precast units. Lightweight concrete blocks, e.g. those made with foamed slag or clinker aggregate, may require even a weaker mortar than the 1 : 2 : 9 mix. With foamed-slag concrete blocks the substitution of fine foamed-slag aggregate for a part of the sand has been made with successful results.

Cutting and fitting hollow blocks around windows, gables, etc., presents some difficulty, and the manufacture of a multiplicity of specials is expensive. It is probably better to carry out such work with smaller solid units which can be cut and fitted like brick. The use of the same material for the smaller and for the standard units is desirable in order to avoid differences in suction which may affect applied plastering, external rendering and thermal insulation.

If only for appearance, concrete block walls of this type are usually rendered or otherwise treated externally.

Pier and Panel Construction

The "pier and panel" forms of construction were introduced after the 1914–1918 war in order to economise in skilled bricklayers' labour and brick. The essential features of such systems are the erection of precast or built *in-situ* piers or posts and the formation of panels between them of concrete blocks of standard dimensions.

The most frequent troubles which arise in this form of construction are cracking between the posts and panels, failure of adhesion to the posts of the external rendering and, less frequently, cracking and deformation of the walls caused by expansion due to the use of unsuitable aggregates for the walling units.

Such troubles can be overcome by accuracy in erection of the piers, ensuring that when clinker or other lightweight concrete is used for the blocks, the aggregate is sound, and providing an adequate key for the rendering on the face of the piers. It is preferable to reinforce the joints between the piers and panels with strips of wire-netting well bedded in the undercoat of the external rendering as a further precaution against cracking at these points. If the piers consist of precast reinforced concrete, care must be taken to make them of dense material and to ensure that the reinforcement is not placed too near the surface. Otherwise

corrosion and consequent spalling may occur which in time may endanger the stability of the building.

Most pier and panel walls are of cavity construction, and since all concrete masonry has a tendency to crack (due to the drying shrinkage of the building units), cavity gutters should be provided over all openings, and the other usual precautions against moisture penetration should be taken.

(6) Frame Cladding

In fully framed buildings it is common practice to apply to the frame, externally, a weather-resisting but non-load-bearing cladding, which, however, in most instances affords a useful amount of stiffness to the frame. The more common types of cladding are dealt with in the following notes:—

Traditional Cladding of Weatherboard, Tiles, etc. The traditional types of cladding are tile and slate hanging and weatherboarding, the use of which is so well known that little need be said on the subject. It is, however, important that nails of the most durable kind should be used in such constructions, or maintenance costs will be high. The little extra expense involved in the use of non-corrodible nails instead of unprotected steel nails is money well spent. Care should also be taken to avoid fixing damaged or cracked tiles or slates, since replacements can only be made with difficulty.

Tiles and slates used in hanging are exposed to risks of damage by impact which do not arise in roofing. They should therefore be of robust manufacture and brittle varieties should be avoided. Because of the risk of damage, tile and slate hanging is rarely used for the lower storey of a building, and there is, therefore, always the risk that the large amount of water dripping from the lower edge will cause dampness in the walls of the ground floor and injure the work beneath. A good overhang is necessary to prevent such troubles and if possible a gutter should be provided under the cladding, to avoid splashing at the wall base.

Where tile or slate hanging or weatherboarding is continued to a point near the ground-level, it is no less important to take steps to prevent penetration and damage. Stopping the cladding on a projecting member, e.g. a wood, tile or brick sill, results in a risk of both. In all cases the bottom edge of the cladding should be so designed as to throw water clear of the work beneath.

Concrete Cladding. Concrete cladding may consist of modified

forms of concrete block masonry which, although not sufficiently strong to support roof and floor loads, must carry their own weight.

Such cladding is rarely more than three inches thick and may be less. In consequence it will require lateral support from the frame.

The method of support is a matter of importance for several reasons. In the first place, ties or fastenings built into a thin external wall will have little cover and may corrode and cause damage to the walling. Such ties should, therefore, be well protected against corrosion or be made of incorrodible metal. In this connexion it should be mentioned that aluminium should not be bedded in cement or lime mortar, since it may corrode and cause expansion.

A similar problem has to be faced if ties are cast into the walling units during manufacture. Furthermore, if the ties are stressed during fixing or by movements of the frame, damage to the walling units may result.

The lateral support necessary to prevent the buckling of the cladding is not great. The ties therefore need have no great strength. The use of stout copper wire ties for the purpose would appear to be one solution to the problem.

The jointing mortar for thin concrete cladding units should be similar to that referred to in the section dealing with load-bearing masonry. No extra strength or resistance to moisture penetration can be expected by the use of mortar denser than the building unit, and the use of strong mortars with relatively weak units may result in an added risk of cracking and increased vulnerability to moisture penetration.

Steel Cladding. Flat steel sheets have been used successfully as a cladding for timber and steel frames, and in some instances the sheets have been flanged at the joints to act as structural members, thus eliminating the need for a separate frame.

As with other impervious materials, the vulnerability to moisture penetration of this type of cladding depends upon the efficacy of the method of jointing adopted. The firms who originally built steel houses were shipbuilders or manufacturers of steel water-tanks, and they used the techniques for jointing which were in general use in their respective trades. When experienced men are employed to make such joints under competent supervision the result is satisfactory, but in supervising

such work, if there is any doubt regarding the competency of the operatives it is necessary to observe closely the formation of every joint to ensure that they are properly filled and tightened and that a satisfactory filling material is used. The usual jointing materials are red and white lead putty or bitumen, usually reinforced with vegetable or mineral fibre. The use of other materials should be looked upon with suspicion until information regarding their previous performance is available.

Steel sheets used as cladding are exposed externally and internally to conditions conducive to corrosion, and to ensure durability it is important that after they are fixed in position they are adequately protected on all faces and edges. This normally includes a preliminary phosphate treatment to clean the steel and provide a "key" for the paint; a rust inhibitive coat, e.g. a red lead primer, and an undercoat of white lead paint. After erection, one or more coats will be necessary externally for protection and for the sake of appearance.

The painting of steel cladding should be carried out with the utmost care. Should any part of the metal, however small, be exposed to the atmosphere, corrosion will occur and may then spread under the adjacent paintwork. Satisfactory durability and low maintenance costs can only be obtained by strict supervision of the painting processes and careful maintenance.

Asbestos Cement Cladding. Little need be said about the use of asbestos cement sheets as a cladding material. The manufacturers provide full fixing instructions, which should be followed. The main point to be watched is the avoidance of complete rigidity in fixing, otherwise slight movements of the frame will result in fracture of the sheets. This is usually overcome by allowing a certain amount of play between the fixing holes and the bolts or nails.

Cladding with Panels of Composite Construction. Attempts have been made in late years to manufacture composite wall panels which can be used as cladding. These usually consist of two thin sheets with an infilling of insulating material. The framework of the panels is generally of timber, but in some instances metal has been used. Suitable combinations of material are almost unlimited. For instance, the outside sheet may be of sheet metal, asbestos cement, metal lathing or wood wool with an applied rendering, thin reinforced concrete, etc., and the inside sheet of plasterboard, wood fibreboard or asbestos cement sheets. An

insulating layer may or may not be necessary: this is dependent upon the insulating value of the other materials used. Slag wool, wood fibreboard, dry sawdust, etc., have all been employed for insulating purposes.

Usually, panels of this type are a feature of a proprietary method of construction, which may include forms of fixing specially adapted to the type of panel and frame employed.

The common source of trouble with all such constructions is the tendency for the vertical joints to open and permit penetration of moisture, and however efficient in principle the method of jointing adopted by the manufacturers may be, the most careful workmanship and maintenance are necessary to ensure waterproof and reasonably permanent joints. Frequent inspection of the work during and after construction is therefore necessary.

Unless very carefully handled and transported, panels of this type are easily damaged, and when this occurs, satisfactory site repairs are difficult if not impossible. Since even slight damage, e.g. cracks in external asbestos cement sheets, may be a serious source of trouble at a later date, it is advisable to return all damaged units to the factory for repair.

Units with thin reinforced concrete outer skins should be carefully examined for rust marks and cracks. If either occurs it will be probable that the reinforcement is insufficiently protected against corrosion. This may lead to expansion and disintegration of the concrete.

Reinforced Concrete Cladding. Many forms of cladding with reinforced concrete slabs or panels have appeared in recent years. Various mixes and aggregates have been used and the sizes of the units have differed considerably. In many instances the external surface of concrete has been textured and coloured, and sometimes faced with clay tiles to imitate brickwork.

As with all forms of concrete masonry, the drying shrinkage of the concrete, especially in the case of lightweight concretes, renders it difficult to construct vertical joints which will permanently exclude water.

The walls of framed buildings are usually of cavity construction, and dampness can be avoided by the careful design of constructional details. However, shrinkage cracks in the masonry should be reduced to a minimum to avoid the penetration of an excess of water in the cavity and also for the sake of appearance. The proper curing of the units and the use of a satisfactory jointing mortar

are matters of major importance in this respect. The former is covered by a British Standard, and the latter has been discussed earlier.

The tendency in the manufacture of reinforced concrete units is to reduce their weight, either by making them thin or by using lightweight concrete, and either of these changes increases the risk that any reinforcement used will not be adequately protected against corrosion.

Types of concrete claddings which do not depend upon mortar or mastic joints to resist moisture penetration have been evolved in late years but have not yet been used in large quantities. These generally consist of units which lap like weatherboarding or roofing tiles, thus being free to move without the risk of the joints permitting moisture penetration or of the units cracking.

7. Party Walls

The party walls of semi-detached or terraced houses have two important functions. They must prevent the spread of fire and also reduce the transmission of sound from one house to another.

Unfortunately, the construction best fitted to prevent fire spread is not necessarily the most effective in reducing sound transmission. A compromise has therefore to be made.

The bylaws of most Local Authorities require party walls to be of solid masonry not less than 8½ in. in thickness. This adequately satisfies the requirements of the Code of Practice relating to fire protection, but falls short of the desirable standard of sound insultation.

In buildings of conventional construction the safest compromise is to provide a party wall of cavity construction, which will probably be acceptable to most local authorities. For efficient sound insulation, the cavity should not be bridged by any rigid material; wall ties should be as few as possible and preferably made of wire, and the two leaves should be reasonably massive.

If the external walls are also of cavity construction, the cavity in these and party wall should be continuous, and no rigid connexions should be made between the inner and outer leaves of the external wall at window and door openings.

Should the exterior walls be of solid construction, no substantial advantage will be gained by using cavity construction in the party wall unless the external walls are thin in substance and flexible, e.g. steel, or rendered discontinuous by the provision of

a gap closed only by felt packing, a flexible metal strip or other type of non-rigid joint. In the former case the leaves of the party wall should be separated from the external cladding by means of a packing material, e.g. asbestos wool, which is both non-rigid and incombustible.

Party walls in non-traditional forms of construction need individual consideration.

8. Chimneys and Flues

Defective chimneys and flues are sources of inconvenience and high maintenance costs. Their design should therefore be carefully considered, and workmanship should be of a high standard. Some of the various troubles associated with chimneys and flues are discussed below and suggestions made for avoiding them.

(1) Smoky Chimneys

Flues function much as the flow-pipe between a boiler and a hot-water cylinder, and the same principles are involved in the design of both. Heated liquids expand, and are therefore lighter for a given volume than those at a lower temperature. Consequently, as water in a boiler and the flow-pipe is warmed, the column of water between the boiler and the cylinder becomes lighter than that in the return pipe. The heavier column then flows downwards and forces the hotter water up to the cylinder.

A similar action takes place in a flue. As the air in a room becomes warmer than the external air, pressure at the flue inlet increases and there is a tendency for the warm air to rise. If the fireplace is well designed, all the air entering the flue is heated by the fire and the draught of the flue is thereby increased. Normally the longer the flue the greater the draught, because the difference in weight between the hot and cold columns of air is correspondingly greater. As with water in pipes, the rate of flow of gas in a flue can be seriously reduced by quick bends, rough surfaces and obstructions.

The effect of eliminating all ventilation from a room is similar to cutting off the cold supply to a boiler. The upward flow of hot gases in the one case or water in the other ceases.

Wind creates pressure on one side of a building and suction on the opposite side, relative to the air pressure inside the building, and it is most important that a room should not be ventilated in such a way that air is sucked out of it rather than forced in.

To avoid downdraught, therefore, the following conditions must be satisfied:—

(*a*) The room must have sufficient ventilation from the weather side of the building to make good the loss of air rising in the flue and means must be provided to seal all windows or ventilators on the lea side of a room in stormy weather.

(*b*) The flue must have smooth internal surfaces and must not be constricted or obstructed in any way. Sharp bends must be avoided.

(*c*) The fireplace must be so designed that all air entering the flue is thoroughly heated. The principles governing the design of open fireplaces as set out by Rumford are well known and effective.

Size of Flues. No satisfactory means exist at present for determining the most efficient size of a flue. For domestic fires the usual 9 in. by 9 in. brick flue is generally satisfactory as regards draught and ease of cleaning. A circular flue is more efficient than a square flue of approximately the same cross-sectional area.

Short Flues. It is worth considering that with short flues, e.g. those serving rooms immediately below a flat roof, the amount of draught will mainly depend upon the temperature of the gases in the flue. It is reasonable to suggest, therefore, that the design of fireplaces serving short flues should have special consideration, with the object of preventing admittance of any cold air from the flue. This entails restricting the fireplace throat to a minimum. In such cases it may also be advisable to reduce the cross-section of the flue and conserve the heat by insulation. Both objects could be achieved by using a flue-pipe inside the normal chimney, with an air space to separate it from the brickwork.

Chimney Cowls. As has been explained previously, the draught of a flue is controlled by the difference in pressure which exists between the inlet and outlet. Unless these pressures are properly balanced, therefore, the provision of special chimney-pots will have little effect.

(2) Moisture Penetration and Durability

Chimneys are usually more fully exposed to the weather than any other masonry in a building, They require, therefore, special consideration in design and construction to prevent moisture penetration and deterioration of the materials used in their construction.

Only high-quality bricks should be used for chimneys. This not only applies to the facing bricks, but also to those used for forming the flues. It is especially dangerous to use bricks having a high sulphate content when the conditions of exposure are so severe.

The tops of chimney-stacks are especially vulnerable to penetration and should be carefully protected. Where no impervious chimney-cap is provided and the head is formed in brickwork, tiles or other jointed material, a damp-proof course should be inserted as near the top of the stack as is practicable. This is still necessary if the stack is to be rendered, since the rendering may be damaged by frost or sulphates if the brickwork becomes saturated. If the masonry of the chimney becomes wet, the flue will be cold. This will decrease the draught and may result in condensation troubles, which are discussed later.

Another damp-proof course is necessary immediately above the junction with the roof to prevent dampness inside the building. This is advisable in all cases, but more necessary when the chimney is built on an external wall and rises from the eaves.

In some instances there may be a long raking connexion between the chimney and roof. A stepped damp-proof course is then necessary or the chimney flashings should be made continuous with the horizontal damp-proof course. An almost equally good solution to the problem is to build the chimney between the damp-proof course, and a point below the roof intersection, in dense engineering bricks and cement mortar. To render this part of the chimney is less satisfactory, since moisture may penetrate behind the rendering and cause frost damage or sulphate attack.

(3) Flues to Slow-Combustion Appliances, Etc.

The construction of flues which serve slow-combustion stoves, domestic boilers and highly efficient gas boilers needs special consideration. In such instances the flue gases have a relatively low temperature and the flue surfaces do not therefore become warm throughout the length of flue. In these circumstances condensation may be deposited on the colder surfaces of the flue, e.g. where the flue walls are exposed to the external air. Since the flue gases contain acids as well as moisture, the resulting condensate is composed of weak acid. The latter can attack and disintegrate lime mortar, and its effect upon mortar containing cement is even more serious. The attack on the latter results first

in expansion of the mortar and subsequently in disintegration, the effect being that parging mortar decays and falls away, and that the mortar joints of the flue or chimney expand and disrupt the masonry.

The cure for this trouble is not simple. Two methods have been advocated, neither of which is, in all respects, entirely satisfactory.

The first consists of lining the flue with an impervious material. Glazed stoneware pipes have been suggested for the purpose. The advantages of this method are that the acids are positively isolated from contact with the mortar, and that if the pipes are kept out of contact with the brick flue, the air space so formed affords useful thermal insulation. This preserves the temperature of the flue gases and condensation occurs at a much higher level in the flue. In short flues condensation may not occur at all.

However, glazed flue linings are not all that can be desired. They are too smooth to hold the soot deposited upon them and after a time quantities of soot may fall into the fire. Furthermore, any condensate which may be deposited will not be absorbed by the flue walls and consequently will tend to flow downwards into the fire. The latter trouble can be overcome to some extent by continuing the straight flue below the bend used to connect the heating appliance, and forming a chamber with a removable receptacle to collect the deposit.

The second approach to the problem is to dilute the flue gases with relatively dry air and so raise their dewpoint. This can be done by providing an air inlet into the flue from the room side a few feet above the fire. There is little doubt that this method largely overcomes the trouble, but there is then a risk that down-draught may result in the entry of flue gases into the rooms, causing discomfort to the occupants. Back-flap ventilators are not entirely efficient in preventing leakage. Flue gases, even if little smoke is present, may cause the discoloration of some types of paint.

The final solution to the problem has not yet been reached, but the above suggestions are put forward in the light of available knowledge.

9. External Wall Finishes

External walls may be treated to increase their resistance to moisture penetration or for the sake of appearance. Usually, treatments serve both purposes, to a greater or lesser degree.

(1) External Renderings

Where the chief object of an external treatment is to prevent moisture penetration, there is always a temptation to apply a dense, impervious rendering. This frequently defeats its purpose. Dense cement mortar has a high drying shrinkage and the greatest movement occurs after the rendering has set and hardened. This results in the formation of cracks at intervals, the spacing of which is dependent upon the strength of the backing, the adhesion obtained by the rendering, the rate of drying and the richness of the mix. Cracks in a dense rendering act as capillary paths to the body of the wall for the water running down the external surface. If the wall is of relatively porous material it may absorb sufficient moisture through such cracks to cause dampness on the internal face. Furthermore, although water readily enters the cracks, the rendering will prevent external evaporation and the wall will therefore remain permanently damp.

Cement-lime External Rendering. Relatively pervious renderings can be made with cement-lime, the strength of which can be varied to suit the nature of the backing and conditions of exposure. In general, it is wise to use the basic proportion of one part of cement, plus lime, to three parts of sand and to vary the proportions of cement and lime according to circumstances. Thus proportions of cement-lime mortar may be 1 : 1 : 6, 1 : 2 : 9, 1 : 3 : 12 cement: lime: sand, or of intermediate ratios.

As a general guide it is suggested that a 1 : 1 : 6 mix is suitable for application to good-quality concrete or brick masonry, even in severely exposed positions. With less strong backings, e.g. lightweight concrete or on less exposed sites, 1 : 2 : 9 would be more suitable. Weaker mixes than the latter can only be used in relatively mild climates, but then they are more satisfactory than denser mixes for application to weak backings.

The effect of using weak mixes is to reduce the drying shrinkage of the rendering, to cause the crack formation to be evenly distributed and to reduce the widths of the cracks. Another important point is that water entering any cracks which develop is not drawn to the wall surface, but is absorbed by the rendering and spread over its surface, whence, under favourable conditions, it can evaporate.

Relative Strength of Coats of External Rendering. Protective renderings should always consist of two or three coats, the latter being necessary only where the surface of the backing is uneven

or on very exposed sites. In no case, should an applied coat be stronger than the previous coat. The mixes of successive coats can be similar or they can be graded, the strongest being the first applied and the weakest the last.

The danger of applying straight cement mixes to weaker undercoats cannot be over-emphasised: cracking will be inevitable and the undercoats will then become wet. In frosty weather the expansion of the water in the undercoat will cause disintegration and the finishing coats will fall away.

Rough Cast. A rough surface is usually more resistant to penetration than one of a smoother texture, since the water flowing down the wall tends to be thrown clear of the shrinkage cracks. In rough-cast mixes, fine stone chips or gravel can be used to replace the sand in the final coat, which is "thrown on" instead of being applied by trowel.

Preparation of Base for External Renderings. The preparation of the base to receive a cement rendering is of major importance. Adhesion can be obtained by mechanical key or by pure adhesion to the material of which the base is composed.

Mechanical Key. Pure adhesion cannot be relied upon when the base is smooth and impervious, e.g. dense concrete or impervious brickwork built in cement mortar. In such instances a mechanical key is necessary. This can be obtained by raking out the joints of the brickwork during construction, treating the surfaces of concrete when it is poured with a "retarder" or by the application of a "spatterdash" coat to the concrete or brickwork surfaces.

Adjustment of Suction of Base for External Rendering. Unless means are taken to prevent it, the high suction of certain types of walling material may prevent adhesion between an applied rendering and the wall. This is caused by the premature drying of the applied material at the interface between the wall and rendering and an incomplete set of the cement at this point.

The suction should be carefully adjusted by wetting before the rendering is applied. It is not necessary to saturate the wall face, but it should be definitely wet at the time the rendering is applied.

The suction of undercoats also needs adjustment before further coats are applied.

External Rendering on Weak Bases. Should it be necessary to render a wall having a weak or "crumbly" surface, it is inadvisable to apply the rendering, however weak, direct to the surface. The

safest way is to remove all loose material, plug and batten the wall, and apply the rendering to metal lathing supported by the battens. All woodwork should, in such circumstances, be impregnated under pressure with a wood preservative of non-staining character, to protect it against attack by dry-rot. With reasonably sound stone or brick walls it may be possible to omit the battens and fix the metal lathing direct to the wall by means of plugs driven into the mortar joints. In this case the heads of the plugs should be left proud of the face of the wall to ensure that the rendering material is compacted behind the metal lathing and that the latter is completely embedded in the mortar.

When metal lathing is used, it is better to embed it in straight cement mortar rather than to depend upon the weaker cement lime mixes for protection. The following coats can, however, be in the weaker mixes, though to avoid cracking these should not be applied until the undercoat has dried thoroughly. This will entail the provision of a good mechanical key in the undercoat by means of deep scratching.

Methods of Applying External Rendering. All coats of rendering can be applied to solid bases in the normal way by trowel, or thrown-on and afterwards levelled up. The latter method has certain advantages in respect of increased adhesion and open texture. However, it is better to accept the practice of the district rather than to impose a new technique upon the plasterers: the work will thereby be more rapid and workmanlike.

Surface Finish of External Rendering. The surface finishes of renderings is important. Smooth, trowelled surfaces are apt to craze and crack, and it is almost impossible to obtain a smooth surface regular in texture and colour. Possibly the best way of dealing with the problem is to scrape the finished surface before it has fully hardened. This can be done by using steel straightedges, trowels, hack-saw blades, or special tools having nail points projecting at close intervals.

In this connexion, it should be mentioned that the scraping process can only be carried out when the hardening of the surface of the rendering has reached a critical stage. If the surface is soft the scraping will result in the removal of too much material and an irregular surface; if too hard, of a patchy finish consisting of alternating smooth and rough areas. The correct time for scraping is when it is feasible to remove the thinnest possible layer of uniform thickness from the surface without affecting the lower

layers. The time for scraping must be judged on the spot, since weather conditions may be responsible for great variations in the suitable time between application of the finishing-coat and scraping.

In warm weather, application and scraping should be done on the same day. A night's exposure may result in the rendering becoming too hard for the operation to be successful.

(2) Pebble Dashing

Pebble dashing or "dry dashing" consists of throwing on a final coat of small pebbles or stone chippings immediately after the application of the previous coat. For this finish the undercoat should be as strong as the backing will bear—not weaker than 1 : 1 : 6—and the application of the final coat must not be delayed beyond the period taken by the undercoat to stiffen slightly. It is difficult even for experienced workmen to obtain a perfectly regular finish with this type of finish, and it is therefore necessary to watch the work closely to ensure that the day's work is completed at angles of buildings or at projecting features, so that there will be no definite line where the work stops and restarts. This also applies, but not to such an important degree, to "scraped" and other finish coats.

(3) Cement Paints

Cement paints and similar finishes are applied to brickwork and other forms of masonry to reduce the risk of moisture penetration and for appearance. If properly applied these give reasonable protection against moisture penetration for periods of from five to seven years, and are therefore useful as substitutes for rendering. They can be renewed when they become ineffective or dirty.

(4) Limewash and Distemper

Decorative finishes of limewash and distemper are sometimes applied to masonry: they may be white or coloured. For permanency, limewashes should contain tallow, which should be mixed with white quicklime before it is boiled. The suitable proportion of tallow (which should be Russian tallow) is 5 lb. to a bushel of quicklime. It should be finely shredded and laid on top of the quicklime. The latter should then be gradually watered until the heat generated is sufficient to melt the tallow. Thereafter the lime plus tallow can be run to putty in the normal way.

Distempers for external use should preferably not contain organic binders such as casein or organic oil. Especially on the north elevations of buildings, such materials may provide nutriment for mould growths which will disfigure the walls. The most common form of mould appears as black spots and blotches, but sometimes moulds are coloured.

(5) Colourless Waterproofers

A certain amount of weather protection is provided to brick, concrete and stone masonry by the application of colourless waterproofers. These reduce the risk of water penetration through masonry units and mortar by discouraging the entry of water into the pores. It will be obvious that such treatments are not useful to prevent moisture entering cracks of appreciable width in the units or between them and the mortar joints. The useful life of the best colourless waterproofers may be five years or more, but the severity of exposure influences their durability.

10. Internal Wall Finishes

(1) Plasterwork

Plastering gives rise to more troubles than other building work, mainly because craftsmen do not fully appreciate the properties of the more modern materials, but also because the leisurely technique of former times has given way to a demand for speed in all building operations.

The more common defects which occur in plasterwork are discussed in the following pages, but first of all a few notes on materials are given which may help to clarify the description and explanation of the defects.

Materials

Sand. Fine sands, those badly graded and those containing appreciable quantities of clay, all increase the risk of high drying shrinkage of plastering coats.

Sea salts are hygroscopic, i.e. they absorb moisture from the air, and must not be present in plastering sands, since their inclusion may result in periodic dampness.

Lime. The limes most commonly used for plastering are white fat lime (high-calcium) and greystone lime (moderately hydraulic). These can be purchased as quicklimes and also as powdered slaked lime—"hydrated lime"—under various proprietary names.

Hydrated limes should comply with British Standards to ensure soundness.

Quicklimes for plastering must be slaked before use, preferably by running them to form lime putty. A substitute for lime putty can be made with hydrated limes by soaking them in water for 24 hours, but the resulting material is not so plastic as normal lime putty.

Lime putty made from quicklime needs maturing to ensure that all of the material is properly slaked. Reference to the British Standard for building limes should be made on this point. Limes containing particles of unslaked material are said to be "unsound."

Plaster. The various types of gypsum plaster can be roughly divided into the following classes:

(*a*) Gauging plaster, which is normal plaster of Paris. This sets in about fifteen minutes.

(*b*) Retarded hemihydrate plaster, which is plaster of Paris with an addition of a glue-like substance which delays the set for various periods according to the use for which it is required. The set once begun is practically as rapid as that of plaster of Paris.

(*c*) Hard-burnt or anhydrous plasters, which are known generally as "Keene's cement." These set slowly and continuously over long periods, provided moisture in sufficient quantities is available.

(*d*) Plasters intermediate between (*b*) and (*c*), e.g. "Sirapite," "Victorite," etc. These contain a proportion of quick-setting plaster which gives an early hardening effect. Subsequently the slow-setting material—the hard-burnt plaster—also sets, provided the necessary water is available.

(*e*) Anhydrite plaster made from a natural anhydrous plaster, which has generally the same characteristics as Keene's cement (*c*), above.

All plasters expand on setting, but the expansion in (*a*) and the ordinary grades of (*b*) is more marked than in other types.

Manufacturers are usually able and willing to state the type of plaster they sell under proprietary names.

Special plasters are available for certain purposes, e.g. hemihydrates with low setting expansion for use on wall-boards and those with admixtures to prevent the rusting of metal lathing.

Mixes for Plastering Undercoats: Sand and Lime. Undercoat plastering may be composed of sand and lime, preferably gauged

with cement or plaster. Straight-lime undercoats are insufficiently strong to receive any finishing coat except lime or lime lightly gauged with plaster.

The proportion of gauging material should be $\frac{1}{10}$th by volume of course stuff (lime plus sand) in the case of cement, or $\frac{1}{6}$th in the case of plaster. Types (*b*) and (*d*) are suitable for gauging undercoats, but Keene's cement and anhydrite plasters should not be used.

Plaster and Sand. In all cases the mix should be in accordance with the recommendation of the plaster manufacturers.

Cement and Sand. Although a 1 : 3 cement : sand mix is often specified for undercoats to Keene's cement, anhydrite plaster or neat or strongly gauged plaster finishing coats, there are certain disadvantages in using such a strong mix in an undercoat, as is explained later. It is preferable to use a cement-lime mortar or a strong plaster and sand mix.

Mixes for Plastering Finishing Coats. Finishing coats may be of lime gauged with any type of plaster except (*c*) and (*e*) above. The proportion of plaster can be varied according to the degree of strength and hardness required. Neat plaster of any type except (*a*) can also be used, with or without an addition of fine sand.

As explained later, the strength of the undercoats must be adjusted to suit that of the finishing coat.

(2) Common Defects in Plasterwork

Popping and Pitting. It sometimes happens that soon after plasterwork is finished small blisters appear on the surface and subsequently the blistered material falls away, leaving pits in the finished surface.

In the majority of cases this only affects the finishing coat, but sometimes the pits are deep and extend into the undercoat. It will be found that at the base of every pit there is a small fragment of material which has expanded and pushed away a section of the plastering.

Almost all instances of this trouble can be traced to the use of lime which is slaked unsatisfactorily, and therefore contains unsound particles. The trouble can be avoided by careful supervision of the slaking of any quicklime used or by obtaining a guarantee of soundness for hydrated lime from the manufacturers.

Dry-out and Delayed Expansion. Slow-setting plasters (*c*), (*d*) and (*e*) above may dry, and usually do, before the setting process

is complete. This may happen generally or in patches. Normally, this is of no serious consequence, because internal plastering is rarely subjected to damp conditions. However, should it subsequently become damp through condensation, absorption of moisture from the masonry behind it or for any other reason, the unset plaster may resume the setting process and consequent expansion may cause blistering and cracking. This trouble is usually only associated with strong finishing coats of the plasters mentioned. In severe cases the whole of the finishing coat may lose adhesion and fall away.

The initial precautions necessary to reduce the risk of the development of this defect are the avoidance of over-quick drying, such as occurs in the summer with maximum ventilation, and the use of undercoats which can absorb a reasonable amount of moisture, e.g. cement-lime mortar and having the undercoats properly wetted before application of the finishing coats.

It is far more important, however, to prevent the plastering from becoming wet after it has once dried. During construction, unglazed windows, unfinished flashings, plumbing leaks and the like may be a source of trouble. The remedy is to plaster only after the completion of work vital for the prevention of moisture penetration to the plastering, and after the walls are reasonably dry.

Condensation, which is discussed more fully later, may be sufficiently heavy to produce delayed expansion, especially in kitchens and bathrooms, but the more common sources of trouble are the general penetration of moisture through defective walls; local penetration caused by unsatisfactory design or workmanship of constructional details; and the normal drying out of the walls.

Failure to Set. A not infrequent trouble associated with plastering is failure of the plastering mix to set. This is rarely the fault of the material used, but is almost always due to a lack of appreciation of its properties.

The set of calcium sulphate (gypsum) plasters is the result of the growth of minute crystals of gypsum which join together and interlace. If anything occurs to prevent this growth or to break up the crystal structure once it begins to build up, the strength and hardness of the plastering is seriously affected.

In buildings erected during wet weather the walls are frequently very wet when the plastering is applied, so that they are unable to

absorb the excess mixing water from the applied plastering. If, in addition, the atmosphere is damp, and this must always be the case in a new building of conventional construction, the plaster will remain wet for a long time. In these circumstances the plaster crystals may not form at all or may be dissolved in the surplus water after they form. The remedy is to delay plastering until the walls are reasonably dry and the atmosphere is not unduly humid.

When hemihydrate plasters (*a*) and (*b*) are used neat, or in strong mixes, the commencement of the set is unmistakable and there is no excuse for applying partially set material. However, in sanded undercoats it is more difficult to judge the exact time at which the set begins, and therefore there is more danger that material will be used during the period when the plaster crystals are growing. Application during the setting period prevents the binding action of the crystals and destroys the usefulness of the plaster.

The approximate time of set of a plaster can easily be determined by making up a small pat of neat material and observing the time taken for it to stiffen. This time will not change appreciably with sanded mixes and they should be applied well before the set is due to commence. They should not subsequently be trowelled. The addition of lime to a mix containing retarded hemihydrate plaster tends to hasten the set. This must be taken into account to avoid killing the set.

Frost can also affect the set of plastering mixes; the effect of frost is dealt with later.

Cracking and Hollowness. Settlements and the warping and deflection of timber are usually blamed for the cracking of plastering, but by far the majority of such troubles are due to movements of the plastering itself.

Plastering mixes containing cement, or lime, shrink as they dry and calcium sulphate plaster mixes expand as they set. The latter, however, may shrink a little finally on drying.

The effect of these movements can be best explained by illustration. If a wet piece of paper, say a photograph, is stuck to a piece of dry cardboard, it tends, on drying, to curl the latter. This is due to the drying shrinkage of the paper. However, if the paper is applied to a rigid base, say a wall, when it dries it stretches and lies flat. Weak papers in such circumstances, especially if the adhesion is irregular, tend to tear.

In a similar way, plastering mixes which shrink tend to curl the

backing or, if the adhesion is irregular, to crack. Similar effects are obtained with calcium sulphate mixes, the expansion of which results in an opposite movement, but with the same tendencies to curling and cracking.

When a mix which expands is applied to one which shrinks, the tendency to curl is increased.

Surface Dusting of Anhydrous Plasters. If conditions are such that the surface of an anhydrous plaster, e.g. Keene's cement, dries at an abnormally fast rate, the crystal formation at the surface is prevented and a thin skin is formed of unbound plaster.

This may have serious affects upon applied decoration, especially on paintwork, as is explained later.

The avoidance of strong draughts over the plaster surface will reduce the risk of this type of trouble, but a more positive remedy is the application of a sharp coat of primer immediately following the trowel.

(3) Precautions Against Failure of Plasterwork

The main safeguards for reducing defects in plastering are:

(*a*) To provide a rigid base. Flexible bases such as metal lathing must be securely fixed and the joints tied tightly. Rigidity is obtained by the application of a reasonably strong first coat and allowing it to set before further applications of plaster.

(*b*) The first coat must have adequate and uniform adhesion to the base. This can be obtained by pure adhesion, as, for example, in the case of a suitable neat plaster applied to plasterboard or by a mechanical key, as with metal lathing.

In many instances, e.g. normal brickwork with raked-out joints, both pure adhesion and mechanical key are obtained.

(*c*) Where reliance for adhesion is placed solely upon the mechanical key, e.g. wood and metal lathing, the first coat must be sufficiently strong to ensure that the plaster keys are able to withstand the stresses set up by the movements of the plaster and also any vibration which is to be expected in the building.

(*d*) Second undercoats are used to level up the first coat in order to provide a suitable base for a thin finishing coat of uniform thickness. The mix should not be stronger than the first coat—in practice the two coats are usually similar in composition. This is not necessary when the first coat is a straight cement and sand mix, as is the case generally on metal lathing. It is in fact preferable, then, to use a cement-lime mortar or a sanded calcium-sulphate plaster mix.

(*e*) The finishing coat also should not be stronger than the undercoat to which it is applied. If a hard, strong finish of neat plaster, e.g. Keene's cement, is required, the undercoats must be strong and properly set before receiving the finishing coat.

(*f*) Where insufficient mechanical key is provided and reliance is placed solely upon pure adhesion, the suction of surfaces to which any type of plastering mix is applied is of vital importance and must be properly adjusted. This does not mean that the surface must be saturated with water. Some surfaces require no wetting, e.g. plasterboard. Dry walls of porous material, such as normal brickwork, need to be wetted sufficiently to prevent a too rapid drying of the mix. On the other hand, with wet walls it may be necessary to allow time for drying before plastering can be satisfactorily applied.

(*g*) With mixes containing cement or lime the mortar should be allowed to dry thoroughly before another coat is applied. This will ensure sufficient strength and also reduce the risk that shrinkage cracks formed in the undercoat will cause similar cracks in the applied coat.

(*h*) Shrinkage cracking must be reduced as far as possible by avoiding the use of dirty sand and conditions conducive to excessively rapid drying, e.g. as caused by central-heating systems.

(*i*) Fine cracking or crazing in finishing coats can be avoided by properly adjusting the suction of the undercoat and by avoiding trowelling after the material has become too dry for the success of the operation.

(*j*) Abnormally rapid drying conditions must be avoided when anhydrous plasters are used. When dry, the plastering should not be exposed to wet conditions.

(4) Wallboards

At the present time the use of wallboards as a substitute for plastering, especially where framed construction is used, has become almost general practice, but it cannot be said that the finish obtained is always satisfactory. The most usual trouble associated with all types of board is unsightly cracking at the joints. This can only be avoided by the most careful attention to workmanship in fixing.

Bearers should be provided under all joints and intermediate bearers, at not less spacing than that advised by the manufacturers of the board, used. In addition, the bearers must be suffi-

ciently rigid to prevent movement at the joints of the boards, caused by pressure or impact.

The edges of the boards should be nailed or otherwise fixed at close centres. Here again the manufacturer's recommendations regarding the spacing of fixings and the type of nail to be used should be followed. Nails for wallboards should be incorrodible or heavily protected to avoid rust stains and they should be well driven home to ensure close contact between the boards and the bearers. Care is, however, necessary to avoid damage to the boards. After decoration, hammer-marks and fractures become unsightly, and damage near the edges of the boards may result in looseness and cracking at the joints.

The types of boards now available vary considerably in properties and behaviour, and the choice of a board for any particular purpose must be governed by its properties.

Wood-wool Cement Boards. Wood-wool cement boards, which consist of tangled wood shavings bound together with cement slurry, give a high degree of thermal insulation provided one surface, at least, is sealed.

Normal plastering can be applied readily, and this will give the necessary seal. It is, however, essential to fix the boards rigidly and to use plastering mixes which do not give rise to high shrinkage or expansion. In addition, it is wise to reinforce the undercoat plastering over the joints with metal or hessian scrim, to reduce the tendency to crack at these points.

Wood-Fibre Boards. Wood-fibre boards are composed of fragments of wood compressed together to form smooth sheets of varying density. The lighter boards are known as insulation boards and the heavier as hardboards. There are intermediate qualities of varying densities.

It is usually unnecessary to plaster insulation board, but if a thin plaster finish is required, the joints should be scrimmed and a single coat of hemihydrate plaster used as a finish. The plaster should be of the special low-expansion variety. Alternatively, two-coat work can be used. The makers of the boards can advise on the most suitable materials and procedure for such work.

Hardboards may be preferred when a stronger wall face is required. The joints in this instance should be covered with strips of similar material or wood, or a panelled construction can be used.

The denser varieties of board cannot be plastered satisfactorily, though some plastic paints obtain a good bond to them.

Plasterboard. Plasterboards are well established as a substitute for plastering. They can be finished with one or two coats of plaster or decorated direct. In all cases the success of the work depends upon the degree of care exercised in fixing the boards and making the joints. The manufacturer's instructions should be followed in regard to workmanship and the applied plastering mixes. These instructions are based upon the experience gained over a number of years, and unless they are followed carefully cracked joints are almost inevitable.

Plasterboards have not the high heat-insulating properties of some of the boards previously discussed, and should not be substituted for them unless the wall construction is altered to compensate for the loss of insulation caused by the alteration. The boards give useful fire protection to steelwork, the thickness required for this purpose depending upon the type of steel framing used and on other considerations.

Where the boards are used near the floor level, and consequently exposed to a risk of damage by impact, the bearers should be closer together than elsewhere or a thicker board should be used.

Asbestos Cement Sheets. Asbestos cement sheets can be used as a wall lining, but their properties are such that they are rarely employed for the purpose except in special circumstances. Their thermal insulation value is below that of many of the materials previously mentioned and extra insulation is therefore required in the wall construction. The plastering and painting of asbestos cement presents certain difficulties.

In fixing, the material should be given a certain amount of play. If rigidly fixed, movement of the structure or of the material itself will result in fracture. The nail or screw holes should be slightly larger than normally would be necessary, and they should not be made close to the edges. Where cover strips are used, as will usually be the case, it is possible to avoid any fixing of the sheets themselves by treating them as loose panels.

Reliance should not be placed on asbestos cement sheets as a protection of, say, steelwork or wood against fire. Sudden large variations in temperature may cause shattering of the material.

(5) Plywood

Plywood is sometimes used for wall lining and has many

advantages for this purpose. It is easily fixed by conventional methods; its thermal insulation value is reasonably high; and its decoration can be of a simple character.

Two general types are available: the normal glued ply and the newer resin-bonded variety. The latter does not disintegrate under moist conditions and it is stronger than the former.

When normal plywood is fixed on battens against an external wall it is a wise precaution to apply a waterproofing treatment on the inner face to avoid disfiguration of the wood face by mould growth and also disintegration of the glue used in the manufacture of the boards. Dampness in a cavity is quite common, especially in new buildings, even if no damp penetrates the outer wall.

One of the outstanding advantages of resin-bonded plywood is that the sheets can be jointed by scarfing and glueing in such a way that the joints cannot be detected. Joints of this kind cannot be made on the site, however, since this requires a special process involving high temperature and pressure, they can, however, be used in the manufacture of large factory-made panels.

(6) Special Wall Finishes

Wall finishes of special types are used in relatively small areas for certain definite purposes. Those in most general use are glazed tiling, glass wall lining and glazed asbestos cement sheets, all of which are suitable for kitchens, bathrooms, etc..

Glazed Tiling. Glazed tiling is sometimes a source of trouble; tiles may become loose or they may crack or craze.

Lack of adhesion of tiling can be due to a number of causes. In the first place the unsuitability of the base to which the tiling is applied may be the root of the trouble. In many instances, bathroom, lavatory and other internal partitions consist of lightweight concrete or plaster slabs, or of studding, all of which are liable to be troublesome unless the problem of tiling is approached in the right way.

Lightweight concrete has a high moisture movement and a certain amount of drying shrinkage is inevitable. This shrinkage results in a compression of the tile facing which, if the adhesion is poor, will cause outward buckling of the tiled surface, and individual tiles or areas of tiling will fall away. Again, such partitions are relatively weak in structure, and if a thick, strong coat of cement mortar is applied to receive the tiles, the base may not be sufficiently strong to restrain its drying shrinkage. A slight

bowing of the partition may then occur, and again there will be a risk of the compression of the tiling and consequent failure.

The most obvious way of overcoming this type of trouble is to provide for the tiling a rigid base which does not have a high moisture movement. Brickwork or clay-block partitions are more suitable for the purpose than those mentioned above.

Where this substitution cannot be made, rigidity can be increased by incorporating metal lathing in the cement mortar undercoat. The lathing should be firmly fixed at close centres, and if possible the treatment should be applied to both sides of the partition, even if only one side is to be tiled. The lathing will also tend to reduce the overall shrinkage of the cement mortar undercoat.

The same treatment can be used in the case of stud partitions, though these, again, should not be used as a base for tiling when it can be avoided.

The adhesion of tiling usually fails at the interface between the tiles and the bedding mortar. This is natural since the latter would be expected to hold more firmly to the undercoat of cement mortar than to the tile. However, the greater the adhesion obtained between the mortar and the tile, the less risk there is of failure.

Lack of adhesion of mortar to tiles is usually caused by a failure to adjust properly the suction of the tile before applying the mortar. Normal wall tiles have a very high suction, which must be reduced by wetting, but if the tile is saturated, this will again result in lack of adhesion. It will usually be sufficient to immerse the tile in water for three or four minutes, remove the excess water and fix it immediately. The fixing mortar should not be too wet, and should be applied firmly to the back of the tile in a central blob, the mortar being sloped off to nothing at the edges of the tile. The tile should then be tapped back level into its correct position. Wall tiles cannot be properly fixed by pressing them back into a recently applied screed.

Keene's cement can be used for tile fixing on the usual cement mortar undercoat. The procedure of fixing is the same as that described above, but the fixing coat is usually less thick. Keene's cement should not be used for fixing purposes if the wall to which the tiling is applied is in a wet condition or likely to become damp later.

A failure of adhesion can also occur when tiling is applied to

brick walls subject to moisture penetration, but this should not arise in the case of a well-constructed house. In such instances the trouble is caused by the penetrating water carrying sulphate salts in solution to the cement mortar. This results in chemical reaction between the salts and the cement, causing expansion of the cement screed and lack of adhesion between it and the tiles.

Glazed Sheet Materials. The methods of fixing glass and glazed asbestos wall lining, etc., are similar. The lining is usually in large panels, which are fixed not by solid bedding but by means of isolated patches of adhesives of various types, e.g. painter's putty, bitumen mastic, Keene's cement, cement mortar, plaster of Paris, etc.

With asbestos cement panels, the fixing should preferably be by means of cement mortar. In no case should an oil mastic or one capable of staining the asbestos cement be used, or the glazed surface will become discoloured. Alkalis in the asbestos cement may affect the oil in mastics and reduce adhesion.

Solid bedding, besides being costly, may be the cause of the cracking of large panels of expensive material.

This work is usually entrusted to specialist firms.

Cracking and Crazing of Wall Tiles. The cracking and crazing of wall tiles may have no more serious consequences than disfigurement of the wall surfaces, but this should of course be avoided if possible.

Cracking occurs usually as a result of shrinkage movements in the backing or undercoat. When the tiles have good adhesion the whole wall system moves as one unit under the stresses set up by the shrinkage of the wall or applied renderings, and major cracks may develop. The use of unsuitable sands in the undercoat and bedding mortar tends to increase drying shrinkage. Clean, well-graded sand is essential for this work.

Most glazes on tiles are subject to crazing. When backed by cement mortar the normal irregular application of the mortar results in slight distortion of the tiles due to non-uniformity in drying shrinkage. This causes fine cracks in the glaze, which in ordinary circumstances are not very noticeable. Crazing becomes unsightly when colouring matter penetrates from the back of the tiles through the glaze and emphasises the pattern formed by the crazing. This occurs usually as a result of damp penetration through the wall to which the tiling is fixed.

11. Solid Ground Floors and Floor Finishes

(1) Sub-Floors

The proper construction of the foundation or sub-floor of solid ground floors is a factor of major importance for the success of the floor finish. It must be level and true, provide good adhesion and prevent the rise of moisture from the soil. The emphasis to be given to these points is dictated by the type of floor finish to be used.

For all types of finish it is essential to reduce movement of the sub-floor to a minimum, since any appreciable shrinkage or expansion may result in failure of the floor finish. Expansion may also cause serious damage to the walls of the building.

Shrinkage can be reduced by laying the concrete as dry as possible and, where necessary, by the provision of suitable reinforcement. In large areas the upper layer of the floor or the cement screed may well be divided into areas about 10 ft. by 10 ft. by means of strips of bitumen felt.

Expansion usually occurs as the result of using concrete aggregates such as unsound clinker, brick of poor quality or material with adherent plaster.

As explained previously, contamination from unsuitable hardcore underfilling can also be a source of similar trouble.

Surface Finish of Sub-floors. The adhesion of a floor finish to its base depends on several factors, the importance of which is dependent upon the type of finish to be used. In general, the surface of the concrete must be clean and strong. Where a mastic flooring is to be applied a slightly rough surface is to be preferred, but smoother surfaces are more suitable when the floor finish is fixed with adhesives.

The manufacturers of the floor finish usually specify the requirements for their particular product.

Damp-proof Membranes. Some floor finishes are unaffected by moisture, but it is necessary to keep others dry. Damp-proof membranes incorporated in the construction of the sub-floor are necessary for the latter. They are also desirable for the former, unless the floor finish is in itself waterproof.

(2) Floor Finishes

The various kinds of finish are discussed below.

Cement Concrete Paving. Cement concrete paving includes the

paving now commonly described as granolithic, terazzo and cement and sand screeds. All are usually almost impervious to liquid water and not appreciably affected by moisture. However, no concrete is completely impervious to water vapour and such pavings cannot be relied upon to act as damp-proof courses. Unless a certain amount of dampness can be tolerated, e.g. in wash-houses, dairies, outhouses, etc., an impervious membrane should be incorporated in the sub-floor where concrete pavings are used. This is especially important where the floor is to be covered with linoleum or other similar floor covering, since water vapour rising through the concrete may condense under the covering. In the case of linoleum this will cause buckling and rapid deterioration. The damp-proof membrane can be of bitumen, pitch or bitumen-felt with lapped and sealed joints, but bitumen emulsion, not being completely impervious to water vapour, is unsuitable. The membrane should be laid in the body of the sub-floor and care should be taken to ensure an even and continuous layer, which should extend vertically behind the upper part of the sub-floor. Where practicable, the membrane should be connected to the wall and partition damp-proof courses.

Cracking and Hollowness of Concrete Paving. The most common trouble experienced with all concrete pavings is that of cracking accompanied with hollowness. This is caused by differential drying shrinkage of the paving and sub-floor, accompanied usually by poor adhesion between the two.

Since the paving is required to be dense and hard, it will necessarily be richer in composition than the normal mix of the sub-floor, and therefore have a higher drying shrinkage. When the sub-floor is relatively dry and has, therefore, already undergone a certain amount of shrinkage before the paving is laid, the relative movements of the two layers will be more pronounced.

Variation in movements can be reduced by making the period between laying the sub-floor and paving as short as possible, preferably by laying both in one continuous operation. The shrinkage of both can be reduced by laying them as dry as is practically possible.

If the paving is laid upon the sub-floor immediately after its completion, there will be no risk of a poor bond between the two layers, but if the sub-floor is allowed to stand for any length of time, the surface will become dirty and adhesion will be poor. Even if the surface is clean, good adhesion cannot be expected

between new and old concrete without very careful preparation. This consists of removing all loose material from the surface of the sub-floor and chipping or wire brushing the surface to expose the aggregate. The sub-floor should then be treated with neat cement grout well brushed into the surface and the paving laid immediately.

Large areas of concrete paving should preferably be broken up into smaller areas about 10 ft. square by means of strips of bitumen felt, metal or other suitable material. This will ensure that cracks caused by shrinkage will occur preferentially at the joints, thus avoiding ugly map-pattern cracking.

Dusting of Concrete Paving. The "dusting" of concrete paving is usually due to the wearing of a weak top layer of cement laitence. If the paving is laid as dry as possible and not over-trowelled, this film will not form and the risk of "dusting" will be reduced. The use of soft or otherwise unsuitable aggregate can, of course, give rise to "dusting," as also can the unsatisfactory practice of trowelling dry cement into the "green" paving.

A useful precaution against dusting is to treat the finished paving with a solution of sodium silicate of a suitable grade sold for the purpose. Two coats are necessary, the first being allowed to dry before the second is applied.

Surface Hardeners for Concrete Paving. There are proprietary treatments for concrete paving for which it is claimed that a harder wearing surface is obtained and dusting is prevented. The manufacturers supply information regarding application.

The wearing surface of floors, steps, etc., can also be improved by sprinkling carborundum powder over the unset concrete and lightly trowelling. This also reduces the slipperiness of the floor.

Tiled Floors. The main difference between a tiled floor and concrete paving is that the tiled surface does not shrink on drying to any appreciable extent, and in consequence it is put into compression by the shrinkage of the sub-floor and screed. If the stresses set up in the tiling are too high to be restrained by the adhesion obtained between the tiles and screed, the former will buckle upwards. Sometimes this happens in localised areas, but frequently almost all of the tiles lose adhesion.

This type of failure is infrequent where the area of tiling is small, say normal room size, unless special circumstances occur to accentuate the shrinkage of the sub-floor or to reduce the adhesion of the tiles. Early application of central-heating systems

can cause the former and excessive vibration the latter. For this reason, tiled floors in well-heated factories in which heavy machinery is installed are more liable to give trouble than others.

A rise in temperature and consequent expansion of the tiled surface after it has become stressed by the shrinkage of the sub-floor is frequently the final cause of failure. Large paved areas exposed to the sun during hot weather are particularly liable to this type of trouble.

The usual precautions, e.g. using concrete mixes as dry as possible, should be taken to reduce shrinkage of the sub-floor, but in addition it is advisable to provide resilient joints at, say, 10-ft. intervals.

The continuation of the joint through the top layer of the concrete sub-floor will assist in reducing the stresses set up in the tiling by localising the shrinkage movement of the concrete. Alternatively, large areas of sub-floors under tiling should be reinforced by 6-in.-mesh welded steel reinforcing fabric to control the shrinkage.

Method of Laying Floor Tiles. Paving tiles may be dense in structure and have little suction. With these, no good purpose is served by soaking them in water before laying. More porous tiles should, however, be wetted before being laid. There should, however, be no excess of water on the back of the tiles or on the surface of the cement screed, since this may result in the formation of air or water bubbles and prevent intimate contact between the surfaces. Sliding the tiles into place rather than placing them directly in their final position assists in preventing the formation of water-pockets.

Tiles are laid with open joints on a thin cement mortar screed. The joints are subsequently grouted with neat cement. It is important that the excess cement grout be properly cleaned off before it has time to harden or the tiles may be permanently disfigured. Cleaning is facilitated by sprinkling sawdust on the grout while it is still wet.

Floor Tiling on Sand Bed. On the Continent, floor tiles are frequently laid on a bed of compressed sand. The method has the advantage of overcoming the troubles associated with the drying shrinkage of the sub-floor. There appears to be no reason why a floor comprising a layer of concrete, a bitumen damp-proof course, a layer of compacted sand, say 1 in. in thickness, and tiles laid in cement mortar and grouted, should not be satisfactory.

The foregoing notes refer particularly to clay tiles, but similar precautions are necessary with rigid tiles of other dense and impervious materials.

Asphalt and Pitch-Mastic Paving. Asphalt and pitch-mastic paving should be undertaken by specialist firms, whose advice should be sought with regard to the preparation of the sub-floor, the grade of mastic, cleaning methods, etc.

Effects of Oils, etc., on Asphalt and Pitch-Mastic. It is important that such floors should not be used in positions where conditions are likely to be injurious to them. In particular, they should not be used where there is a likelihood of oil, petrol or grease being spilt, for this will result in the softening and deterioration of the surface. Polishes containing oils are injurious and may cause softening and affect the colour.

Point Loads on Asphalt and Pitch-Mastic. Asphalt and pitch-mastic tend to flow under pressure and it is therefore advisable to provide support for heavy point loads, e.g. the feet of baths or specially heavy furniture or fixtures. This can be done by the use of hardwood blocks laid in the necessary position on the sub-floor and set in the paving.

Effect of Heat on Asphalt and Pitch Mastic. With this type of floor it is advisable to use fireplace hearths of a larger size than usual to avoid softening by excessive heat from the fire. Should it be necessary to use them on floors liable to become hot, e.g. over boiler chambers, insulation should be introduced below the floor as a protection.

No damp-proof course is required in the sub-floor when asphalt or pitch-mastic flooring is used. Both are impervious to and unaffected by water and water vapour. Where possible they should be connected to the damp-proof courses provided in the external and internal walls.

Jointless Floors. There are a number of different types of jointless floorings which, although similar in appearance, vary in composition and properties.

Magnesium Oxychloride Floors. The most commonly used floor in the past was magnesium oxychloride flooring, known rather vaguely in the building industry as "composition" flooring. Skilled specialists should be employed to lay such flooring, and they should guarantee that the work is carried out in accordance with the Code of Practice. Where this flooring is used, a damp-proof floor membrane is essential.

Anhydrite Floors. Anhydrite flooring is composed of gypsum anhydrite. Although it is a new type as far as this country is concerned, somewhat similar floors have been used on the Continent for many years. Specialists should be employed to lay such floors and a damp-proof floor membrane should be provided.

Sawdust Cement Paving. Sawdust cement can be successfully used as a flooring material, but the precautions necessary to obtain satisfactory aggregate, a correct mix and a proper water content, render it advisable to have such floors laid by experts. A damp-proof floor membrane is required.

Linoleum. Linoleum floors laid on cement screeds have been widely used in late years—but not always with success. The most common trouble which arises with linoleum is the collection of moisture underneath, followed by buckling and deterioration.

The collection of moisture results from the condensation of water vapour rising through the concrete floor on to the underface of the linoleum. The buckling of the latter is caused by the wetting and consequent shrinkage of its fibre webbing.

The remedy is to provide a damp-proof floor membrane and to lay the linoleum only when it is certain that the upper layer of the sub-floor is dry. Since even thin layers of dense concrete take a matter of months to dry, the laying of the linoleum should be delayed as long as possible.

If there is any doubt as to whether the floor is sufficiently dry to receive the linoleum or not, a small square of the latter can be laid on the surface for a few days to determine whether moisture collects under it.

Wood Floors. Wood floors can be laid on concrete by nailing to embedded fillets, to a screed of nailable concrete, or by using a suitable adhesive.

Timber Floors Nailed to Fillets. Ordinary floor boarding, either square-edged or tongued-and-grooved, can be used satisfactorily on solid concrete floors provided the flooring and the fillets to which it is nailed are protected against moisture.

Fixings for timber flooring may be obtained by bedding timber fillets on the sub-floor. These should be dovetailed with the wider part embedded in the concrete. Their top surface can be flush with the concrete surface or project above it. In both cases the fillets should be impregnated under pressure with creosote or other suitable wood preservative, and unless a damp-proof membrane is incorporated in the body of the sub-floor, the concrete

surface and the fillets should be treated with a continuous coat of bitumen mastic other than a water emulsion. When the fillets project above the concrete and a space is provided under the flooring, the treatment suggested will obviate the necessity for ventilation of this space.

Flooring Nailed to Concrete. An alternative method of laying flooring on solid concrete floors is to screed the concrete with a 2-in. layer of coke-breeze or clinker concrete and to nail the boards direct to this.

Floors of this type can be satisfactory, provided workmanship is of a high standard. The proportions of the mix for the screed are important, since if it is too hard the nails cannot be driven and if too weak they will not hold. A suitable mix is one part cement, two parts sand and four parts clean, crushed coke breeze or lightweight clinker. The aggregate should comply with the British Standard of soundness. Even when the screed is of correct proportions, the laying of the flooring must not be delayed too long or the concrete will become too hard to receive the nails. The correct time for nailing can only be judged by trial, since weather conditions may affect the rate of setting and hardening of the screed.

Before laying the boards, the surface of the concrete must be covered with a thick, continuous layer of bitumen or hot tar and pitch; bitumen emulsions are not suitable for the purpose. The success of the floor is dependent upon the continuity and effectiveness of this membrane: unsatisfactory workmanship will almost inevitably result in the development of dry-rot. The membrane should be continued vertically up the walls to cover the edges of the floor-boards.

A desirable additional precaution against dry-rot attack is to treat the underside of the boards with creosote or bitumen before laying them.

The best nails for laying floors to concrete screeds are the normal cut floor nails. Wire nails if used should be driven on the skew, but even so the result is not entirely satisfactory.

Wood-Block Floors. Wood-block floors are laid upon cement and sand screeds in bitumen mastic. The latter acts as a damp-proof course, and any laxity in laying it will create a risk of dry-rot attack.

The moisture content of the wood blocks is important. Those which have a high moisture-content will shrink after laying and

the joints will open; very dry blocks when exposed to the damp atmosphere of a new house may expand sufficiently to cause damage to the walls and partitions or to cause buckling of the floor. Shrinkage troubles can be overcome by using well-seasoned blocks and those due to expansion can be largely avoided by allowing a certain amount of play at the edges of the floor. The blocks need not be in close contact with the walls; alternatively, an expansion joint can be introduced. In either case any unsightliness can be hidden by the skirting.

Other Floorings. There are a large number of other types of floors which can be used on solid ground floors. These include tiles of cork, rubber, asphalt, etc., rubber "linoleums" and many kinds of jointless floors.

The incorporation of a damp-proof membrane in the sub-floor is a wise precaution when there is the slightest doubt concerning the likely behaviour of the floor or adhesive under damp conditions.

The laying of all the types mentioned is usually entrusted to specialist firms who take responsibility for workmanship and durability. It is, however, important to ensure that the floors are properly protected against damage until the building is handed over to the owner.

Factory-made Floor Panels. In late years factory-made floor panels of plywood, concrete covered with various finishings, and other materials have been produced which merely require to be laid upon a solid base. Unless a damp-proof course is provided in the sub-floor, panels in which wood or steel are incorporated should be separated from the concrete floor by means of an efficient damp-proof course.

12. Suspended Floors and Floor Finishes

Suspended floors are usually of wood or concrete, and less frequently of steel or of composite construction.

(1) Wood Gound Floors

The main problem with ground floors of timber is to eliminate any risk of the development of dry-rot. By far the largest proportion of outbreaks begin in ground-floor timbers and are not discovered until the fungus has spread to the floor-boards or to woodwork above the floor-level.

Dry-rot. Dry-rot is often considered to be an unfortunate and unavoidable occurrence or is blamed on unscrupulous builders

who use unseasoned timber. Actually it can always be prevented if the causes are studied and the necessary precautions taken to eliminate them.

The fungus can only commence growth if infection is present, if the temperature is moderate and if moisture is present in sufficient quantity.

It is rarely that timber in which the fungus is actually growing is used in a building, but on the other hand few, if any, batches of timber are free from spores of the fungus, which are so minute that they pass unnoticed unless present in large quantities, when they appear as a fine, brownish-red powder. It is virtually impossible under practical conditions to prevent infection, and since in this country the temperature is almost always favourable to the development of the fungus, growth can only be prevented by keeping the timber reasonably dry or by treatments which render it immune from attack.

Anti-Fungal Treatments. As a general rule timber should not be used in positions which necessitate anti-fungal treatments, though in special instances this may be inevitable. It should, however, be realised that mere brush treatments only protect the surfaces to which they are applied and that the body of the timber can still be attacked.

Timber used in damp situations should therefore be impregnated under pressure with one of the well-known preservatives, e.g. creosote, "Toritna," "Cuprinol," etc. The pungent and lasting smell of the first together with its penetrating and staining properties render it unsuitable for use in some situations. The others are non-staining and any smell is only temporary.

The precautions necessary to ensure the protection of untreated timber are dealt with in another section.

Draught Through Floor-boards. A fault of many ground floors is the excessive draught which penetrates the joints of square-edged boarding. The usual remedy is to use tongued-and-grooved boarding, and this is also desirable for purposes of thermal insulation. The use of a waterproof felt or paper draped or swagged from the top of the floor-joists under the floor-boards will also increase the resistance of the floor to heat loss and prevent draught. It is, however, difficult to ensure that the joints are properly sealed and if leakage occurs the treatment has little beneficial effect.

Wall Plates. In late years, on grounds of economy, there has

been a tendency to omit wall plates between the joists and sleeper walls and to build the joists into the external walls instead of supporting them upon fender walls.

The omission of wall plates increases the difficulty of obtaining a level floor and necessitates the provision of other means of fixing the joists on the sleeper walls. Heavy wall plates are unnecessary for either purpose and economy and efficiency can be obtained by using plates of the smallest practical section.

Building the ground-floor joists into solid walls is to be deprecated. It is possible that the ends may become and remain damp. However, with properly designed cavity construction there can be no serious objection to the practice. The amount of moisture absorbed by the ends of the joists which project through the inner leaf of the wall will evaporate rapidly from the surfaces exposed in the ventilated floor space. The moisture content of the timber, should, therefore, never reach the danger-point.

(2) Wood Floors above Ground Floor

The construction of timber floors above ground-level presents few difficulties and the risk of dry-rot attack is almost negligible. Where joist ends are built into solid walls they should be protected by damp-proof material or by a thorough treatment of wood preservative. There is little or no danger of dry-rot when joists are built into the inner leaf of a well-designed cavity wall.

Timber wall plates are unnecessary, besides being a source of weakness to the wall.

Floor Beams. Economy in timber can be effected by shortening the span of the joists by the use of beams of steel or reinforced concrete.

The depth of the joists can then be reduced.

Common Faults in Timber Floor Construction. The common faults in timber floors of cheap construction are floor-joists laid out of level; excessive springiness due to lack of depth in the joists, or overwide spacing of the floor-boards and failure to provide joists almost in contact with the walls running parallel to them. These points should be carefully watched during construction.

The trimming of joists around staircases and hearths is often done in a slip-shod manner, and should be given careful supervision to ensure that well holes are of the correct size, the joints are properly made and that all timber is fixed at a sufficient distance from the fire flues. When hearth fires are used on upper

floors it is important that no timber should be built into the concrete hearth and that the latter is insulated on all surfaces in contact with timber. The use of thin asbestos cement sheets for the purpose is of no value. Slag wool or other incombustible insulating material is more suitable.

(3) Cast *In-situ* Concrete Floors

Cast *in-situ* concrete floors may be of normal reinforced concrete or composed of cast *in-situ* beams with hollow tile filling of clay, concrete, etc.

In most cases floors of this type are laid by specialists, but supervision is necessary to see that openings, etc., are provided where required and to exact measurements. It is also important to see that the floor contractors exercise care in placing the reinforcement in its correct position; that sufficient cover is given to prevent corrosion and to check the level of the floor formwork before the floor is laid.

Where possible, holes and openings should be left in floors for pipes, flues, etc., and the position of these should be checked before any concrete is placed.

If for any reason the concrete floor is carried across the cavity of a hollow wall a continuous sloped damp-proof course should be provided. This is referred to in a later section.

Damage Caused by Shrinkage of Concrete Floors. The drying shrinkage of a cast *in-situ* concrete floor is usually sufficient to produce cracks in the finished plasterwork of the walls on which it bears. The cracks usually take the form of short diagonal shear cracks in the wall plaster immediately below the ceiling. Part, at least, of such cracking could be prevented by laying a strip of bitumen felt or paper between the slab and the walls to form a joint between the wall plastering and that of the ceiling.

(4) Precast Concrete Floors

There are many types of proprietary precast concrete floors. They have advantages over cast *in-situ* floors in that the construction is dry, and that if properly cured the units will have a low drying shrinkage. The proper curing of the units is of importance, since appreciable movement will result in extensive cracking of the ceiling plaster. The units should, of course, be laid in as dry a state as possible or the ceilings will remain damp for long periods.

Stacking Concrete Floor Units. Concrete floor units are heavy

and care should be taken to prevent their being stacked in a leaning position against a "green" wall or the latter may collapse.

Special Units. Floors of precast units should be carefully set out as early as possible so that special units can be made for trimming well holes and to permit the passage of pipes, flues, etc.

(5) Composite Floors

In order to save timber and avoid wet construction, numerous types of floor constructions have been evolved during and since the war. In most cases the tension members are of small steel sections which must be carefully protected against corrosion and fire.

Some of the newer floors are made in large factory-made panels of composite steel and wood construction. With these it is necessary for the adjoining sides of the units to be firmly fixed together to avoid differential movement under load. Unless this is done the weight of heavy furniture concentrated upon one or two panels may cause serious differential deflection of the floor.

In the case of all factory-made floors special units will be required in the formation of well holes, around flues, etc.

13. Roofs

In late years many experiments have been made in the construction of both flat and pitched roofs with the object of effecting economies either in cost or in the use of material in short supply, more especially in the use of timber. The constructions available for flat roofs are those already described for upper suspended floors. Pitched roofs can be supported by members of metal, wood, metal and wood in combination or of precast concrete. The variation in design is unlimited. Apart from ensuring that all metal is properly protected against corrosion, that joints are well made, that timber does not pass through party walls and that point loads, e.g. under trusses, are properly distributed, there are few points of special importance for the building supervisor to watch in this part of the construction.

Those of the first type are usually laid flat or at a low pitch, and the latter at pitches which may vary according to the roofing unit employed.

(1) Jointless Roofings

Roofs may be covered with impervious materials, either laid jointless or with water-tight joints, or with relatively pervious materials lapped and bonded to form a water-shed.

Asphalt. Although when compared with tiling and slating, asphalt seems a relatively new form of roofing material, there is available sufficient experience of its behaviour to ensure a durable and satisfactory job. Asphalt roofs are almost invariably laid by specialist firms who have extensive knowledge of the properties of the material, and in consequence unsatisfactory work is uncommon, though by no means unknown.

In laying asphalt roofs, the tendency of the material to flow must always be considered, and in addition the severe conditions of exposure to the weather, and especially to solar heat, to which flat roofs are subjected, must be taken into account.

The more common troubles experienced and their causes are discussed below.

Cracking on Vertical Surfaces. When asphalt is laid on vertical surfaces, e.g. parapet walls, it tends to flow downwards. If it is held solely by a key or "tuck-in" at the top, the lower portion may gradually pull away and a crack may form at some point below the key. The remedy is to provide keys for the asphalt at short intervals, e.g. by raking out joints in masonry or by providing a continuous key in the form of expanded metal lathing. Provided the degree of hardness of the asphalt is suitable, no trouble of this sort is likely to arise in the case of low skirtings to roof surfaces, but even with these it is necessary to thicken the asphalt at the angles between the skirting and "tuck-in" and between the skirting and the roof covering.

Map-pattern Cracking. Cracking of an irregular pattern—map cracking—may occur in asphalt which has been coated with certain paints or other treatments. The cause of the trouble is that the paint shrinks, and pulls the asphalt. On a roof where the asphalt tends to soften in hot weather the stresses imposed by this shrinkage is sufficient to cause crazing and even more pronounced cracks. If a heat-reflecting surface is required on asphalt it is advisable to provide this by using a lime-wash or a layer of light-coloured stone chippings rather than a paint treatment.

Regular Straight Cracking. It sometimes happens that long straight cracks form at regular intervals on asphalt roof surfaces. These can result from laying the asphalt on paper with either lapped or butt joints. The heat of the sun causes the asphalt to expand and thicken, with the result that there is a tendency for adjoining sections of asphalt to separate at the paper joints. The remedy is to lap the felt beneath the asphalt and to use a type of

felt, e.g. hair sarking felt, the joints of which will be sealed by the heat of the applied asphalt.

Cracks on Sloped Surfaces. Cracks may occur in asphalt on sloped surfaces. These occur as a general rule roughly at right angles to the slope. This trouble may also include the pulling away of the skirting at the top edge of the slope. This again is caused by changes in temperature giving rise to alternate expansion and contraction which causes the asphalt to creep towards the lower part of the roof. It is wise to provide a key such as metal lathing for any asphalt surfaces which have an appreciable slope, and to ensure that the material is of the grade of hardness most suited for the purpose. The asphalt contractors are in a position to advise on the last point.

Blistering. Round excrescences may appear on asphalt roofs, especially on concrete roofs. These are usually caused by pressure of air or of water vapour. In the case of concrete roofs, which are frequently asphalted before they are completely dry, the heat of the sun causes expansion of any moisture vapour or air which is present at the interface between the concrete and asphalt and lifts the asphalt locally from the concrete surface. The action is cumulative, since when the roof cools a partial vacuum occurs inside the blister, and further moisture or air is drawn in. When the roof again becomes hot further expansion occurs and exerts pressure on the asphalt. The blister consequently increases in size and, in time, fracture may occur.

The way to avoid this trouble is to lay the asphalt upon a suitable felt which will permit any moisture vapour free movement beneath its surface. In this way isolated pockets of moisture cannot be formed and if expansion occurs the asphalt surface moves as a whole, obviating the formation of isolated blisters. Even when this precaution is taken the concrete should be as dry as possible when the asphalt is laid.

Asphalting in wet weather may result in the entrapment of water in or under the material, which may ultimately give rise to blistering. This can occur on boarded as well as upon concrete roofs.

Built-up Felt and Bitumen Roofing. Built-up felt and bitumen roofs are almost always laid by specialist firms, who are usually prepared to give a guarantee of performance over a reasonable period.

Satisfactory durability can be obtained by applying further top

dressings of bitumen and grit, or sand, periodically. This should not, however, be necessary more often than once in five years.

Where built-up roofs are used in positions which may be used for foot traffic, the roof is sometimes covered with tar-macadam, cast concrete slabs, etc. Such surfaces may tend to hold water, and the felt roof is thus kept permanently damp. This creates a risk of rotting and cracking of the roofing felt.

Roofs of this type can be whitewashed to provide a reflecting surface, or alternatively a light-coloured sand can be used to "blind" the top dressing of bitumen. Paint can cause crazing and cracking of the top dressing in the same way as it cracks mastic asphalt.

Metal Roofs. Lead, copper, zinc, aluminium and steel sheets have been used for roofing purposes, and it seems likely that, with modern methods of production of thin sheets, their use will become more extensive in the future.

Long-term experience is available concerning the durability of the three first-named roofings. In the case of aluminium, experience is limited, and it is known that steel must be carefully protected or corrosion may be rapid.

Corrosion by Acetic Acid. It is only when extraordinary conditions prevail that lead, copper and zinc lack durability, but all are rapidly corroded when exposed to an atmosphere containing acetic acid. Such conditions may obtain in vinegar and pickle factories, breweries, and even in buildings used to store old barrels previously used for vinegar, beer, wines, etc. It is almost impossible to protect the metals completely from attack, and it is therefore safer to use other materials, e.g. asphalt and bitumen. There is also reason to believe that aluminium will give reasonably good service under these conditions.

Zinc Roofing. Zinc in normal circumstances can be considered durable; it has been used extensively with satisfactory results in this country and on the Continent.

Steel Roofing. Unprotected steel deteriorates rapidly under normal conditions. If the material is used for roofing, great care should be taken to ensure that a satisfactory protective treatment is provided in the first place, that the treatment is not damaged during construction and that there is no likelihood of damage to the protective treatment, e.g. by foot traffic when the building is complete.

Corrosion by Electrolytic Action. Corrosion can occur by

electrolytic action when different metals are in contact and slightly acid water is present. The latter condition is almost universal and it is therefore necessary to avoid contact between the metals. It is always safe to use nails, fixing clips, etc., of the same metal as the sheets, but only in exceptional circumstances to use other metal for the purpose. For instance, rapid corrosion of the zinc can occur when copper and zinc are in contact.

Condensation. The subject of condensation under metal roofs is dealt with in a later section.

Jointing. There are many methods of jointing metal roofing sheets, most of which experience has shown to be satisfactory. The subject of jointing will be covered in the relative Codes of Practice.

It is reasonable to suggest that all metal roofs, except perhaps lead flats, the proper construction of which is known to all good plumbers, should be entrusted to specialist firms.

(2) Roofs of Lapped and Bonded Units

Tiled Roofs. Roof tiling is almost as old a trade as bricklaying and there is little, except what is well known, that can be said about it. However, a few matters affecting the weather-proofness and durability of tiled roofs may be considered.

Weather-proofness. Even a properly laid tile roof is never completely air or watertight. It depends upon the water-shedding action of the lapped tiles for protection. Moreover, a large number of tiles, although satisfactory in use, are not of themselves impervious and moisture penetration is only prevented because the tiles usually dry before they absorb sufficient moisture to produce dampness on the inner face.

The chief danger of moisture penetration occurs when rain or snow is driven by strong winds underneath the lower edges of the tiles. This trouble is overcome in various ways in different parts of the country, e.g. by torching or pointing, laying the tiles on boarding, or by laying felt immediately below the tiling battens. In all cases the effect is to prevent a through-current of air carrying rain or snow inside the house. Torching has certain disadvantages which are discussed under durability, but, if carefully done, boarding or felting is satisfactory.

Alteration in Pitch. The pitch of the roof may be suddenly altered, the most usual instance being when a sprocketed eaves is used for the sake of appearance. This frequently gives rise to

moisture penetration since, if the pitch of the main roof is only just sufficient, that of the eaves will be too flat to prevent rain or snow being driven in. Even with a steeply pitched roof this danger is to some extent present, because there is a sudden check in the flow of water where the pitch changes and the greatest concentration of water therefore occurs at that point.

The risk of penetration can be reduced or eliminated by increasing the lap of the tiles on the lower pitch and by providing a lining to the tiling.

Cement Fillets. In cheaper buildings it is common practice to substitute cement fillets for lead flashings. The initial economy effected is more than outweighed by the trouble from moisture penetration which arises when cracks form in the fillets, or between them and adjoining materials, as a result of drying shrinkage.

Durability. Roofing tiles can deteriorate as a result of frost action or by the crystallisation of salts.

Frost. Most trouble from frost occurs with machine-made tiles of poor quality, which may have a laminated structure with air pockets between the laminations. Tiles of this type tend to draw moisture into the voids between the laminations, and during frosty weather expansion, following the freezing of the entrapped water, bursts the tile.

Crystallisation of Salts. Certain types of tile which are relatively permeable and also contain appreciable quantities of soluble sulphate salts deteriorate rapidly. There is a danger that the nibs of such tiles will disintegrate and the tiles become detached. This is caused by moisture from the exposed face passing through the body of the tile and evaporating on the nibs. During its passage through the tile the water dissolves the salts present which crystallise in the pores of the tile as the water evaporates. The resulting expansion has a disintegrating effect on the tile structure.

The manufacturers can frequently produce test data to show that their products are reliable. Failing this, an inspection should be made of roofs covered with similar tiles to those it is proposed to use, in order to discover whether there are signs of lamination or disintegration.

Damage by Nailing. Brittle tiles are easily broken by careless nailing. Experienced tilers can judge exactly how far a nail should be driven, but less skilled men are apt to drive them too far and break the tile.

Care should be taken to see that no damaged tile is left in the roof to cause trouble at a later date.

Slate Roofs. Slating is another ancient trade of which little new can be said. The durability of slate roofs depends upon the quality of the slates and the type of nails used.

Durability. Slates of inferior quality are attacked and disintegrated by weak acids. In industrial areas, therefore, only a short life can be expected from them. Where any doubt exists as to the quality of the slates, enquiry should be made as to their previous behaviour on other buildings.

The British Standard for Welsh slates ensures satisfactory quality, but there are many other British and Foreign slates, which are adequately durable, for which there is no British Standard at present.

The nails used for slating should be of incorrodible metal or protected against corrosion, e.g. by galvanising.

Pointing. In the northern counties, when roof boarding is not provided it is common practice to point all the joints between the slates internally. The local opinion is that the severity of the weather renders this essential. It is probable, however, that the provision of felt behind the slates would obviate the necessity for pointing.

Asbestos Cement Roofing. Asbestos cement roofing is manufactured in the shape of tiles, e.g. pan-tiles, diagonal and normal slate pattern, corrugated sheets, large roofing tiles with corrugated laps and purlin tiles.

Used in accordance with the manufacturers recommendations and in compliance with British Standards and the Codes of Practice, asbestos cement roofing is satisfactory and durable.

Thatch or Shingled Roofs. The foregoing roofing materials are those in most common use, but certain others are employed less frequently. For instance, thatch and wood shingles. The main objection to both types is that there is a danger of fire from sparks or burning fragments from other buildings, chimneys, etc.

Buildings with thatched or shingled roofs are therefore, in this country, controlled in regard to spacing between buildings and in regard to the least permissible distance between the buildings and boundaries and highways.

Methods of "fireproofing" thatch have been evolved in the past, but the greater proportion of treatments rely upon water-soluble

salts which may be leached from the thatch by rain. In general, therefore, the protection of thatch by fireproofing liquids or treatments is impermanent.

Thatch is likely to harbour vermin such as bugs, fleas, rats, mice, etc., and birds may make nests in it or remove the thatch for this purpose.

The usual method of dealing with birds is to enclose the eaves and verges in wire netting, but it is difficult to suggest a method of dealing with the more elusive vermin.

(3) Roof Drainage

Rain-water gutters and down-pipes may be made of cast iron, pressed steel, zinc, lead, asbestos cement, aluminium or precast concrete.

The ordinary practice regarding rain-water gutters and pipes is well known, and therefore may be passed over, but the more unusual materials need comment.

Pressed Steel. Pressed steel is very vulnerable to corrosion and it is necessary to ensure that adequate protection is applied in the first place and that any damage done to the protective coating during erection is properly made good upon completion.

Zinc. Zinc has been used extensively for roof drainage and even in industrial areas has proved durable over long periods. It is, however, usual to protect the metal by painting.

Precast Concrete. The dangers with precast concrete gutters are first that the drying shrinkage of the concrete may result in open joints and leakage and that owing to the small sections used the reinforcement will be placed so near the surface of the concrete that it will rust. Rusting of steel results in expansion, which may cause spalling and disintegration of the units.

If precast concrete gutters are used it is essential to ensure that the reinforcement is properly embedded in dense concrete, and it is preferable to line the gutter with a continuous membrane of suitable metal, bitumen or bitumen felt.

Impact Damage to Down-Pipes. The main troubles associated with rain-water pipes are impact damage to the lower portions and leakage at the joints.

Few types of rain-water pipes are damaged by anything other than heavy impact blows, and it is therefore futile to substitute, say, cast iron for asbestos cement, zinc, etc., at the base of down-pipes in the hope of avoiding damage. The problem can best be

solved in the design stage of a building by placing down-pipes where severe impact blows are not to be expected.

Jointing of Down-Pipes. The jointing of rain-water pipes is of almost equal importance to that of soil pipes. Leakage at joints invariably leads to dampness inside the house, resulting in damage to decorations and plasterwork.

Joints should be carefully made in mastic bitumen. Red and white lead putty is also suitable.

Valley Gutters. The traditional materials for valley gutters are lead and zinc, both of which are necessarily laid on wood for support. In late years sheet-steel, cast iron, asbestos cement and asphalt have been used for the purpose, the latter being laid usually on wood or concrete.

The two major points to be considered in the construction of valley gutters are:

(*a*) To ensure that the outlets are sufficiently large and that means are provided to keep them open. Otherwise the gutters will fill and water will spill over the sides, causing serious leaks in the building. Valley gutters should therefore have a good fall, with outlets of ample capacity, and grids should be provided to the outlets to prevent chokage by leaves, silt or other materials.

(*b*) Self-supporting valley gutters are usually of thin metal or other material that provides practically no thermal insulation. In cold weather, therefore, or after a heavy fall of rain or snow, condensation is likely to occur on the underside of the gutters and water will drop into the building. All valley gutters should be insulated internally and means should be taken to prevent access of warm, damp air from the building to the undersurfaces. This matter is discussed under "Condensation."

14. Partitions

One of the commonest defects encountered in buildings is the cracking of partitions or the plaster applied to them. The causes are excessive moisture movement of the material used in the construction, and, more rarely, structural movements caused by settlement, deflection of beams or thermal movements of the roof. The cracking of plastering, as distinct from cracks which occur in the partitions themselves, is discussed under "Internal Wall Finishes."

Brick Partitions. It is unusual to require great strength in

partition walls, and furthermore they are not exposed to damp or extremes of temperature. For these reasons it is permissible to use bricks internally which would not be considered suitable for use in external walls. Brick for partitions will therefore tend to be less strong and more permeable than those used for external walls, and may also be somewhat more irregular in shape.

It is unnecessary and in fact undesirable to use dense cement mortar in building non-load-bearing partitions. A cement-lime mortar which, when set, approximates to the density of the brick will give better results, since there will be less risk of crack formation and the surfaces will have uniform suction—an important point when plaster is to be applied.

Irregularity in brick sizes and shape renders it impossible to obtain perfect brickwork. In thin walls one surface at least will be uneven and the bonding will not be uniform. Neither of these points constitutes a major defect, though should the wall be so uneven that the plaster has to be of abnormal thickness or to vary excessively in thickness, the risk of the cracking of the plaster will be greatly increased. Irregularity in brick sizes can be tolerated therefore only to a limited extent.

If sand-lime or concrete brick are to be used in partitions it is important to build the walls as dry as possible or serious cracking may result. The brick should only be sufficiently damp to avoid a "dry-out" of the mortar and the latter should be a cement-lime mix used as dry as possible. No brick of either kind should be used for partitions of inferior quality to that required by British Standards for internal purposes.

Concrete Slab Partitions. All classes of lightweight concrete have relatively high moisture movements and unless precautions are taken to avoid it, cracking often occurs in partitions built of this material. The necessary precautions are similar to those described previously for concrete and sand-lime bricks but special care is necessary to ensure that the blocks are not allowed to become appreciably wet in storage or after they are used. Appearance is often deceptive and a sufficient degree of dryness can only be obtained by storage under cover for a reasonable period.

Slabs which comply with British Standards should be satisfactory when delivered, but defects can develop in the finished work unless care is exercised in storage and erection.

Cracking over Door Frames. The greater the length of a partition the more risk there is of the development of vertical shrinkage

cracks. As a general rule, however, partitions are interrupted at fairly frequent intervals by door openings.

In such circumstances the tendency will be for any shrinkage cracks which develop to occur between the door head and the ceiling. The means usually adopted to prevent this is to carry the door jambs above the head and securely fix the projecting parts to the ceiling. Above the head the jambs can be made thinner to accommodate the plaster, and the space between them filled with slab walling. Strips of expanded metal projecting 3 in. to 4 in. on both sides of the jambs can be embedded in the undercoat plastering, thus reinforcing the most vulnerable part of the wall. Alternatively, the space above the door can be filled with a fanlight. Any shrinkage cracks will then be hidden by the architrave.

Door-frames, if grooved to receive the slabs, also act as supports to the partition and reduce the risk of damage caused by the slamming of doors.

Partitions immediately under concrete roof slabs should, however, not be wedged tightly at ceiling level, since shrinkage or thermal movements of the slab will produce shear cracks in the partitions. A strip of hair felt can be substituted for the mortar joint at this point and covered by the ceiling plaster, picture-rail or cornice.

Plastering on Partitions. The subject of plastering on partitions is dealt with under "Internal Wall Finishes."

15. Ceilings

The methods used for the lining of ceilings are similar to those used for walls and partitions and are dealt with under "Wall Finishes." However, it should be mentioned that the fall of a ceiling may involve serious damage and inconvenience. For this reason, special attention should be given to the key provided for plastering and to the fixing of laths, ceiling boards, etc., especially when the latter are plastered. It is also important to ensure that the plaster applied to lathing is of sufficient strength to hold by means of the keys to the lathwork.

16. Timber Finishings

Joinery, including wood finishings, is usually painted and used in positions where it is unlikely to become wet. If, therefore, it is of good quality when delivered and care is taken to protect it, prior to fixing, from the weather and other harmful influences, it should be at least as durable as other elements of the building.

The chief duties falling upon the supervisor of a building in this connexion is to ensure that all joinery is well made and of good-quality timber, properly fixed, not damaged in fixing and is protected where necessary against damp and excessive heat.

Damage in Fixing. Except in high-class work, grounds are no longer used for fixing skirtings, picture-rails, etc. Reliance is usually placed on plugging or building-in fixing-bricks, usually composed of clinker or coke-breeze concrete. With plugging it is necessary to avoid damage to the walls. Unless very carefully driven, a series of plugs in a light wall, e.g. a partition wall or the inside leaf of a cavity wall, can cause cracks in the brickwork and to applied plaster.

The use of lightweight concrete fixing blocks necessitates the use of nails of a larger size than would otherwise be necessary. This often results in small members, such as picture-rails, being split or damaged by the nail heads. Such damage is always visible after decoration and must be avoided as far as possible.

Protection against Moisture. When timber is built into external walls or is in contact with surfaces which are washed frequently, e.g. floors, and therefore liable to become wet periodically, it should be carefully protected. It is usual to creosote the backs of door-frames, etc., and although this has some effect in preventing fungal growth, it does not deny access of moisture to the wood. In exposed positions moisture will find its way through the treatment, and may cause swelling of the wood or damage to the paintwork. The use of a good primer and an undercoat of paint instead of the creosote is to be preferred.

The surfaces of timber with exposed end grain are more vulnerable to moisture penetration than others and should, therefore, be given careful attention. Door-frames resting on floors which are likely to become wet periodically should be raised from the floor and seated upon a damp-proof course. Particular care in painting the horns of the heads of windows is necessary.

Oil and Creosote Stains. Oil and creosote stains are almost impossible to eradicate or cover and when these materials are used the utmost care should be taken to avoid bringing them into contact with wood, floorings of a porous nature, plaster or other absorbent materials.

Thresholds to Internal Doors. In hanging doors it is usual to make allowance for the thickness of the floor covering, but in

some instances, e.g. housing schemes, the thickness of the covering will not be known. Possibly the simplest method to adopt is to provide thin, hardwood thresholds under the doors to allow for the thickness of the linoleum or carpets. This has the advantage of reducing draughts under the doors.

Protection from Heat. In centrally heated buildings care is necessary to protect joinery from excessive heat.

It is necessary in some cases to take pipe runs through cupboards or in ducts under timber floors. The pipes should then be lagged.

17. Decoration

The more common defects associated with decorations, and the necessary precautions for their avoidance are discussed below:

(1) Lack of Adhesion

Paint may part from its base by peeling, flaking or blistering. In all cases the original adhesion must be suspected. As with plastering, the provision of a suitable base is essential to success.

Oil paints dry and harden by the evaporation and oxidisation of the oils used in their composition. During the drying process they tend to shrink, and it is therefore necessary to provide a surface that will restrain the shrinkage of the paint. In the case of most building materials the surface is sufficiently rough to give a certain amount of restraint and sufficiently porous to give adhesion, but in certain instances special preparation of the surface is necessary. Smooth metal is a difficult subject for painting, but modern chemical processes are available which give the necessary key for the primer. The preparatory treatment and priming can only be properly carried out in the factory.

Very dense, highly polished plaster surfaces fall almost in the same category as smooth metal. Such surfaces are not essential for good paint finishes and it is preferable to avoid excessive polishing.

Metal, wood or plaster with wet or moist surfaces cannot be satisfactorily painted. Adhesion will be poor and blistering or peeling will therefore result. In this connexion it should be realised that although the surfaces of wood or plaster may appear to be dry it is possible that moisture in relatively large quantities may be present below the surface. This may be drawn to the surface after the application of the paint and cause local blistering or general lack of adhesion.

Loose material present on a surface to be painted, e.g. rust on metal, unset plaster on certain plaster finishes (see "Internal Wall Finishes") or dust on any kind of material, will prevent adhesion and so be a source of trouble.

The composition of the primer or faulty workmanship in application may also be a cause of failure. Primers may not give the base sufficient protection against water penetration and corrosion or disintegration of its surface may therefore occur, followed by failure of the paint film. The application of coats of paint of too great a thickness or of successive coats too rapidly can also lead to lack of adhesion.

(2) Saponification of Paint Films

Cement, hydraulic lime mixes and ash mortars contain alkalis which may reach the wall surfaces while the walls are drying. If paint or oil-bound distempers are applied too early to walls in which such materials are used alkalis may attack the oils in the paint and soften and destroy the paint film. The remedy is to decorate only when the walls are dry or to use a distemper not having an oil base as a temporary decoration and to apply the final decorations at a later date.

Where paint is to be applied to concrete, cement renderings or asbestos cement, special anti-alkali primers should be used, but even then it is still necessary to delay decoration until the walls are reasonably dry.

(3) Mould Growth

The development of moulds in paints or distempers is distinguished by the appearance of black or coloured spots or blotches on the wall surface. These stains consist of minute growths of fungi which feed upon organic matter such as oil or casein present in the paint or distemper.

Moulds only grow under conditions of persistent dampness, and no trouble of this sort should be encountered in a well-constructed new building. It is, however, to be noted that condensation can be a source of this trouble and for that reason new buildings especially should be well ventilated.

(4) Disintegration of Distemper

Distempers sometimes disintegrate and fall from walls in a fine powder and on other occasions they come away in large flakes leaving the wall clean. These troubles are due to the suction of the

wall surface being too high in the first instance and too low in the second. The application of a coat of size to an absorbent wall usually reduces suction sufficiently to prevent powdering of the distemper, but some treatments may eliminate all suction and so by preventing adhesion give rise to flaking.

(5) External Painting

No external painting should be done in wet or frosty weather or when the sun is excessively hot. In the first instance the paint may not harden and will almost certainly lose colour, and in the second blistering is probable.

18. DRAINAGE

Drainage goods are covered by British Standards and a guarantee can be obtained from the manufacturers that the goods purchased from them comply with the requirements of the British Standard.

It is not intended here to describe the procedure to be adopted in laying drains. This is covered by the Codes of Practice. There are a few points, however, in connexion with drainage that require emphasis.

After drains are laid and tested any defects which occur may remain undetected for long periods. All operations in connexion with drainage work should therefore be carefully supervised.

(1) Damage to Drainage Goods

Stoneware drainage pipes and fittings are easily cracked or otherwise damaged in transport and should therefore be carefully examined on delivery. Chipped sockets and damaged glaze are readily seen, and cracked pipes can be detected by tapping them gently with a hammer. All defective pipes and fittings should of course be rejected.

Damage of the protective coating of iron drainage goods may also occur in transit. Some soils and soil waters corrode cast iron very rapidly and any damage to the protective coatings should therefore be made good with hot bitumen before the pipes are used.

(2) Uneven Bedding of Drains

The most likely source of trouble is the uneven bedding of drains, with the consequent risk of fracture at a later date. The harder the ground the more likely the bedding is to be unsatisfactory. Where, due to the presence of rock, it is impossible to

obtain a level bottom, the excavation should be deeper than necessary and a level bed of concrete provided to receive the pipes.

Where the sub-soil is soft the drain trench should be wider than usual and the drains laid upon a bed of concrete.

Encasement of Drains. The complete encasement of drains in concrete only becomes necessary when the drains are shallow and the ground above them is heavily loaded or traffic other than pedestrian traffic is to be expected. Under buildings or roads shallow drains should preferably be of iron and encased in concrete. The latter can be reinforced when conditions are unusually severe.

(3) Refilling of Trenches

The careless refilling of drain trenches may lead to fracture of pipes after the system has been tested and passed. The first foot at least of the filling should be of soil not containing stones. This should be carefully compacted before the main filling is commenced.

(4) Joints

Since all drain-pipes of good quality are waterproof, the main risk of leakage is at the joints.

Joints of Stoneware Pipes. The joints of stoneware pipes are made with cement mortar, which must be as dense as possible to avoid seepage. Sufficient density can be obtained by using fine but well-graded clean sand and cement in equal proportions. The mortar should be used as dry and as fresh as possible. It should have a consistency similar to soft glazier's putty, but the practice of allowing it partially to set and then "knocking it up" again should not be permitted. All joints should first of all be carefully caulked with gaskin to avoid fouling the drain with mortar. The caulking should only fill one-quarter of the joint, which should then be filled with mortar carefully pointed at a slope. Obviously the bottom part of the joint, being difficult to make properly, is the most likely to give trouble. Only skilled workmen should be employed in jointing, since it is difficult to detect faulty joints until the drains are tested.

As the drains must be tested before the trench is refilled, the new joints must be protected from rain, frost or sun. Wet sacking is probably the best protection, except against frost, and the easiest to handle. Dry sacks should be used if frost is expected.

Jointing of Cast-iron Pipes. Lead joints are preferable to

cement joints for iron pipes. The latter are more liable to crack than the former should the drain settle slightly or if, before the trench is refilled, expansion and contraction of the drain occurs through variations in temperature.

Lead joints are made with molten lead or with lead-wool. In both cases it is necessary to caulk the joint with gaskin, the pipes being kept in position during this process by means of steel wedges.

Molten lead joints can be run by using a clay former or a special jointing ring. After the lead is poured it must be well caulked all the way round to fill any voids left by contraction of the caulking metal. The pipes should be dry when the lead is poured or steam may form holes in the joints.

Lead-wool joints are made by well caulking the metal over the gaskin, which is fixed in the same way as described above.

There are many patent joints for drainage, most of which are satisfactory and may be useful, especially under adverse conditions of weather.

(5) Manholes

Manholes should be watertight to ensure that if a choke occurs in the system, sewage is not allowed to escape into the surrounding soil. If reliance is placed upon brickwork for this purpose it must be built of dense engineering bricks in dense cement mortar, and workmanship must be of the highest standard.

Manholes may, however, be rendered internally to prevent leakage. In such cases, a less dense brick is to be preferred so as to provide adhesion for the rendering. The brick, however, should be reasonably hard, well burnt and low in sulphate content, or water seeping through the brickwork may give rise to sulphate attack on the rendering and mortar joints, resulting in expansion and, ultimately, serious damage to the masonry.

(6) Testing

It is usual for local authorities to supervise tests for airtightness on drainage systems and it is sometimes considered necessary before the trenches are filled to ensure that no obstructions occur in the drains. This can be done by rolling a ball, slightly less in diameter than the pipes, through the various lengths. With careful workmanship and strict supervision, however, obstructions should not occur.

19. Lightning Conductors

It is doubtful whether the risk involved in this country warrants the expense of providing lightning conductors on small buildings. Large buildings and especially high buildings in isolated positions should, however, be protected.

Useful protection cannot be obtained by fixing a single earthed terminal to the highest point of the building. It is necessary to affix a number of terminals to such points as chimney-stacks, gable apexes, parapets, etc., and connect them together. The system should then be separately earthed at two or more points.

On the whole, copper is the best metal to use for lightning conductors. It has good qualities of resistance to corrosion and has high conductivity.

Lifts, heavy machinery or other large masses of metal in buildings should be separately earthed, preferably at more than one place. Any joints between different metals, e.g. steel and copper, should be carefully protected from moisture, or electrolytic action may cause corrosion and break the electric connexion.

20. Plumbing and Hot Water Supply

When properly designed and installed, plumbing systems should give little trouble and require no maintenance for a long period. That systems are frequently a source of trouble, and that high expenditure in repairs is often incurred, is an indication that many matters of importance are not given sufficient attention. The following notes deal with the more frequent causes of trouble and their remedies.

(1) Corrosion of Lead by Free Lime

Lead, otherwise one of the most durable of metals, corrodes when in contact with free lime. Free lime is present in new concrete and in fresh lime and cement mortars, but in the course of time it becomes carbonated by contact with the air. In the interior of thick walls built with dense cement mortar or inside a mass of concrete, carbonation is a lengthy process and the lime may remain active for several years. To be on the safe side all lead pipes which are embedded in walls built of cement mortar or in concrete should be protected against corrosion. This can be done either by providing sleeves for the pipes, wrapping them in bitumen felt or treating them with a heavy coat of bitumen paint.

(2) Corrosion of Metal by Acid Salts

Most metals are attacked and corroded by acids and acid salts. The latter occur in certain jointless floorings, e.g. magnesium oxychloride, and in hard-burnt plasters such as Keene's and Parian cement. Protection of a similar kind to that suggested above is necessary for metals in contact with these materials.

(3) Corrosion of Iron and Steel Pipes

Iron and steel pipes are subject to corrosion under almost any normal conditions of exposure. They should be protected by galvanising or by painting. In the latter case the pipes should be clean and bright before painting is commenced, and the first coat should be of a rust-inhibitive type, e.g. red lead.

(4) Electrolytic Corrosion

Corrosion may occur in plumbing systems in which more than one metal is employed. For instance, the use of copper tubes and a galvanised cistern in the same system may lead to the rapid deterioration of the cistern. Even the parings from copper or brass pipes or fittings, if allowed to fall into a galvanised cistern, may produce holes in the latter. This type of corrosion is caused by electrolytic action between the metals. It is generally safe to use the same metal for piping, cisterns and cylinders, taking care to exclude small particles of other metals from the system. No trouble from electrolytic corrosion is to be expected, however, when lead pipes are used in conjunction with galvanised cisterns and cylinders.

(5) Frost

When water freezes it expands and the stresses set up are sufficiently great to burst even strong vessels and tubes in which it is contained. The bursting of pipes is, of course, the most serious result of frost, but great inconvenience can be caused by local freezing, which may cut off the water supply or block waste pipes.

It is unnecessary here to discuss the mechanics of pipe bursts. The following notes are concerned with prevention of the trouble.

A cold-water service pipe should never be less than 2 ft. below the ground level until it enters the building. Its entry should be well inside the building, preferably near a chimney flue which is in constant use in the winter. From this point it should rise,

preferably on the walls of the chimney breast, to the storage tank.

If the tank is situated in the roof space, the former should be insulated on all sides and the insulating material should be protected against damp. The service pipe above ceiling level should be lagged, or otherwise insulated, and the insulation should be continued to and connected with the tank insulation. The pipe lagging should also be protected by a waterproof membrane, e.g. bitumen paint, to prevent its becoming damp.

Branches from the service pipe and tank should, where possible, be taken down and along inside walls. If fixed to external walls, unless these are already well insulated, the pipes should be lagged or carried on back boards.

If the building is equipped with a hot-water system, the cold storage tank may be placed near and above the hot tank.

Since it is impossible to insulate the outlets of waste pipes, there is always a danger that these will become blocked with ice during frosty weather. Dripping taps are the usual cause of the trouble, and these should be repaired without delay. Nothing can be done while the building is under construction to prevent this particular trouble at a later date, except to provide wastes of adequate size and satisfactory tap washers.

(6) Fractures in Lead Pipes

The sagging of a horizontal lead pipe between its supports or the pull of long vertical pipes on their top fixings may in time lead to fracture at the point of support. Movements due to changes in temperature may accentuate this trouble. The support for horizontal pipes should be as continuous as possible, e.g. a small wooden ledge, and the fixing should not be so rigid as to prevent slight movements. As far as possible, long lengths of vertical pipe should be avoided, but where these are inevitable, supports should be provided at short intervals and the fixing should be firm. In such circumstances large variations in temperature should be guarded against, e.g. a lead cold-water pipe should not be placed near a hot pipe unless the latter is lagged.

Embedding pipes in cement mortar provides a completely rigid fixing and movements in the free portion of the pipe may result in damage at the junction of the free and fixed lengths. Embedded pipes can be wrapped in paper to permit slight movement and so prevent stresses building up at this point.

(7) Hard and Soft Water

The properties of the water supplied to a building may influence the choice of plumbing materials. Soft water may dissolve lead in sufficient quantities to affect the health of the occupants of the building or it may increase the risk of electrolytic corrosion. Hard waters may cause rapid "rocking" or "furring" of hot-water pipes and boilers.

Water companies invariably lay down rules regarding the metal to be used with their water and strict observance of their regulations is a safeguard against the first trouble.

Where the water supplied is hard, the only sure remedy for "rocking" in hot-water systems is to provide an efficient water-softening apparatus.

(8) Knocking

There are various explanations of the cause of "knocking" in water pipes, and it is therefore difficult to suggest a remedy to suit all cases. It is, however, generally accepted that sudden checks to the momentum of water in long lengths of pipe or the use of hard or ill-fitting tap washers can cause or accentuate the trouble. Care should be taken to ensure the use of suitable washers for all taps.

(9) Airing Cupboards

Two faults are common in the design of airing cupboards, namely the provision of highly efficient insulation to cover the hot-water cylinder and pipes in the cupboard; and failure to seal the holes through which the pipes from the boiler enter the cupboard.

The result of the first is to reduce the amount of heat available for heating the clothes. It should be remembered that the clothes and the cupboard itself act as insulators, and that highly efficient lagging is unnecessary in this position. Complete absence of lagging may, however, result in the clothes becoming scorched.

The effect of leaving unsealed pipe holes at the base of an airing cupboard is that dust and fumes may be drawn into the cupboard and contaminate the clean clothes. All spaces around the pipes should be sealed. Since the pipes will move with changes in temperature, the material used for sealing must not be of a rigid nature. A jointing material such as asbestos wool, if tightly packed, is suitable for the purpose.

21. Gas and Electric Installations

When gas or electric supplies are provided in a building, the regulations of the local authorities concerned must be followed, and, furthermore, installations are usually undertaken by specialist firms. In the circumstances, therefore, this work is not discussed here. Codes of Practice are in the course of preparation for all service installations.

Part II

THE PROTECTION OF MATERIALS AND WORK UNDER CONSTRUCTION

The effects of weather and, to a lesser degree, other sources of damage, play an important part in the ultimate durability of a building and certain precautions are necessary to avoid future trouble.

The protection of the finished building from the weather depends upon the design of constructional details and is dealt with in other sections.

The following notes are mainly but not wholly concerned with the effects of weather on stored materials and on unfinished work.

1. Protection of Materials

Most building materials (including manufactured articles) are affected by extremes of temperature or humidity or by both in combination. The effects, which may be physical or chemical, are discussed below.

(1) Cements, Lime and Plasters

It is, of course, well known that the exposure of cements, limes and plasters to wet conditions results in the setting of part of the material and consequent waste. For this reason such materials are usually stored under reasonably dry conditions. However, it is possible for them to get damp without actual contact with water, and this may have important results. In the case of cement, the outside layer may set and become useless and with hydraulic limes the effect is similar, but with hydrated non-hydraulic or moderately hydraulic limes, no set may be noticeable although deterioration will occur. Prolonged exposure to a damp atmosphere will result in partial carbonation of the lime and the ultimate strength and hardness of the mortar or plastering mixes in which the material is used will be reduced.

If set particles of plaster of Paris or of retarded hemi-hydrate plaster are incorporated in a plastering mix, the rate of setting

will be increased, and this in severe cases may result in the killing of the set during application.

For these reasons it is necessary not only to store these materials under cover, but to ensure that they do not come into contact with the damp soil or remain for a prolonged period in a damp atmosphere.

(2) Sand and Ballast

Obviously it does not matter whether sand and ballast are stored in the dry or not, but the conditions of storage must be such that the material does not become contaminated with harmful elements during storage. For instance, if they are piled in contact with ashes they may become contaminated with chlorides or sulphates, or if they are placed directly on the ground, soil may inadvertently be included in the mortar or concrete.

Although it is not always practicable, it is preferable to store sand and ballast on a clean platform out of contact with other materials or with the soil.

Although it is usually impossible to store aggregates under cover, it must be realised that sands and porous aggregates can take up large quantities of water. In using wet aggregates for concrete or plastering, the quantity of mixing water should be suitably adjusted.

When wet aggregates are exposed to frost, films of ice may form around the particles. Aggregate in this condition should never be used, since the effect of the ice film is to prevent adhesion between the particles and the cement. In this country frost rarely affects a layer of aggregate more than a few inches thick, but care must be taken to prevent appreciable quantities of frozen material from being mixed with material withdrawn from the centre of the pile.

(3) Storage of Lightweight Aggregates

Modern lightweight aggregates, e.g. foamed slag, have a weak and friable texture, and if these are stored in a high pile the material at the base may be crushed by the weight of the superimposed material. This will result in bad grading due to the inclusion of a high content of fine material or dust. If it should be necessary to store a large quantity of material of this kind, it should be stacked in a flat pile not more than 4 ft. to 5 ft. deep.

(4) Precast Concrete Units

Since all concrete products have a high moisture movement, it follows that if they are wet when they are incorporated in a

building, the risk of shrinkage cracking will be increased. This especially applies to concretes made from lightweight aggregates such as foamed slag, clinker, etc.

The need for dry storage of precast concrete units will therefore be obvious. With dense concretes protection from the damp soil and covering with a tarpaulin will be adequate, but whenever possible, lightweight concretes should be stored inside a reasonably dry building and protected against rain during transport.

(5) Stone—Natural and Reconstructed

Many types of stone both natural and artificial are porous, and in consequence stains caused by contact with dirty water will extend well below the surface and cause permanent disfiguration. Care should therefore be taken during transport and storage to keep stone out of contact with staining material, especially if the latter is wet. Hardwood shavings and straw used for packing, or soil, may be a source of trouble in this respect. The splashing or dripping of dirty water during rain-storms, or from nearby building operations, should also be avoided.

(6) Brick

As with stone, porous facing brick can be spoilt by contact with staining material or contaminated water and should be afforded protection.

When concrete or sand-lime bricks are used precautions should be taken to prevent their being built into a wall in a saturated condition as this will increase the risk of shrinkage cracking.

(7) Timber and Timber Products

Timber should be stored under reasonably dry conditions. It must be realised that the usual shop priming of joinery is not wholly resistant to moisture penetration and that primed articles exposed to damp conditions may obtain a high moisture content. This involves future trouble with shrinkage, warping, and damage to the finishing coats of paint.

Carcassing timber does not require elaborate precautions in respect of storage since it can usually dry out in the building itself. Nevertheless, open stacking and protection against rain and sun are desirable. Dry floor-boards and wood blocks, especially when they are kiln dried, should be kept in dry storage until they are used.

In some forms of construction, timber may be fixed in

unventilated spaces, e.g. in flat timber roofs. In such cases it is well to ensure that the timber used is quite dry or to allow the space to remain open until it has dried. Spaces of this kind should, where possible, be ventilated even when dry timber is used.

Creosoted timber, especially if pressure impregnated, should be stored out of contact with other materials to prevent the staining of the latter. Creosote penetrates porous materials rapidly and the stains are almost impossible to remove.

(8) Steel

A slight amount of corrosion of heavy-section steel members is not of serious consequence provided the subsequent cleansing and paint treatments are adequate. But when lighter section steel members or sheets are used even slight corrosion is serious. Provided the steel is properly painted before delivery, the main precautions to observe are: to transport and store it in such a way as to avoid as far as possible damage to the paint and to make good any unavoidable damage immediately.

Steel should be stored out of contact with soil or sand contaminated with sea-water, clinkers and ashes. Chlorides which may be derived from these may cause rapid corrosion of ferrous metals.

(9) Wall-boards

Almost all wall-boards are adversely affected by moisture. They should be transported and stored under dry conditions to avoid warping, loss of strength, and in many cases high drying shrinkage. Sheets handled separately should be carried on edge, but it is preferable to stack sheets in piles on the flat to avoid warping.

Any materials used for the purpose of thermal insulation should be kept dry, since their qualities of insulation usually depend upon their porous structure and are seriously impaired by the absorption of moisture. This is especially important in the case of materials used in filling factory-made units for walls which are faced with impervious material on both sides. In such circumstances there is no chance for the insulation material to dry after fixing and its effectiveness may be lost. Apart from the loss of insulating properties, such wood products as sawdust or sheet material composed of wood waste may, if wet, be attacked by dry-rot when enclosed in a sealed space.

2. Wilful or Accidental Damage

Practically all building materials are vulnerable to accidental or wilful damage.

THE PROTECTION OF MATERIALS AND WORK UNDER CONSTRUCTION

By far the greater proportion of damage which occurs to materials on a building site is caused by children, but unfortunately older people are often responsible. As far as possible children should not be allowed to use the site as a playground and unauthorised visitors should be discouraged, especially after working hours. The employment of a capable watchman is usual on most sites and is a sound investment.

Damage by workmen is commonly the result of poor site organisation. Materials easily damaged should be stored where they are out of the way of actual building operations, and on no account should materials to be used in the building be permitted to be used as plant or for protection of other materials or of work under construction.

3. Protection of Work During Construction

Unfinished building work is extremely vulnerable to damage by exposure to the weather and by children or sightseers. Sometimes the damage is immediately apparent and at others it may not be noticed until it is too late to rectify it in a proper manner.

Nearly all damage by the weather is the direct or indirect result of the work becoming excessively wet. The presence of water may of itself set up certain types of trouble, or damage may be caused to wet materials by frost. Suggestions for protective measures are discussed below.

(1) Concrete

Hardened concrete of good quality is not damaged by water or frost but while it is in an unset condition both can affect it. For instance, the surface of concrete pavings, steps, etc., can be pitted and ruined by heavy rain or by becoming frozen. Unless severe frost is expected the protection of the surfaces by means of tarpaulins, or other sheet material, supported a few inches above them is all that is necessary, but if hard frost seems likely, some added thermal insulation is desirable. Reasonably dry scaffold planks covered with a tarpaulin can be used, but wind must be prevented from blowing between the planks and the concrete surface.

In very hot weather concrete surfaces should be kept moist for seven days after laying and protected from the sun. Wet sacking is often used for the purpose, but the use of dirty sacks may result in objectionable staining. It is preferable to support the sacking in such a way that it is out of contact with the concrete.

(2) Brickwork and Masonry

The top horizontal surfaces of unfinished brickwork are extremely vulnerable to moisture penetration. Sulphate attack on mortars or disruption by frost may occur in saturated brickwork and may cause damage to the upper courses necessitating rebuilding. It is not always possible to see the full extent of the damage and there is always the risk that defective work will be incorporated in the building. Furthermore, the wall if unprotected at the top may become excessively wet to a depth of several feet and take longer than usual to dry after the building is complete.

For short periods simple methods of protection are sufficient, e.g. bitumen felt, corrugated steel sheets, etc., suitably held in position. Should it be necessary, however, for brickwork to remain in an unfinished state for long periods, the protection must be of a more positive and permanent character.

Sometimes, through lack of funds or for other causes, a building is erected in sections and there is a delay of months or even years between the completion and the commencement of successive sections. The result is that walls designed as internal walls are required to resist moisture penetration and prevent heat loss. These walls may be built with such features as fireplaces projecting externally, and nearly always toothed brickwork is provided to make a bond between the completed and the proposed sections of the building.

No makeshift methods of protection should be permitted in these circumstances. The vertical faces of the walls should be finished by the application of an efficient external rendering or carefully pointed and treated with cement paint of good quality. All horizontal projections from the wall should be flashed with impervious material, and particular attention should be given to making the joints between the flashing and the wall impervious to moisture. The protection of the toothings is a difficult problem, but the safest method would appear to be to case them with an impervious material, e.g. cement rendering on expanded metal lathing. If for any reason it is necessary to leave the top surface of a wall in an unfinished state, this should be protected by providing copings of concrete, tiles, metal, etc. If the coping is jointed, a damp-proof course should be provided underneath.

The above precautions are necessary to avoid moisture penetration into the completed section of the building, damage by frost and, where the bricks used contain appreciable quantities of

sulphate salts, expansion and disintegration of the mortar by sulphate attack.

Similar precautions are also necessary when the masonry is of stone or concrete.

During the erection of walls there is always the risk that materials or tools falling from the scaffold may cause damage to projecting features at a lower level. These should be cased temporarily as a safeguard, but in addition a kerb should be provided on the inner side of the scaffold to prevent dislodgment of material, tools, etc. The kerb will also help to prevent dirty water or material staining the face of the building.

The arrises and mouldings of soft stones, especially when they are freshly quarried, should be protected. The slightest blow can cause damage impossible to rectify in a satisfactory manner.

Woodwork. Exposed woodwork should receive an undercoat of paint over the shop priming as soon as possible after fixing. The priming is insufficient protection to prevent absorption of moisture by the wood.

Wood floors, stair treads, exposed mouldings, etc., should all be protected against damage by foot traffic, by plaster slovens and by the moving of plant, etc.

(3) Plastering

Plastering during and immediately after application is vulnerable to excessively dry or wet conditions and also to extremes of temperature, especially frost. This matter is dealt with elsewhere, Damage to plasterwork by impact of scaffold boards, etc., can only be prevented by the exercise of care. Where possible, finished rooms should be locked to prevent accidental damage and also malicious damage by unauthorised persons.

(4) Glazing

The usual precautions against breakage of glass are to whiten the panes to show that the windows are in fact glazed and to ensure that casements are not left loose to be blown about by the wind.

Glass can, however, be damaged by careless cleaning. If the windows are glazed before plastering is complete, carelessness in this operation and the failure on the part of the plasterers to wash off blobs of plaster while still wet will result in the hardened mortar having to be removed at a later date.

The sand in the plaster, if the latter is carelessly removed, will scratch the glass so badly as to necessitate renewal. An application of weak hydrochloric acid will so disintegrate the mortar that it can be washed away. Care is, of course, necessary in the use of the acid. Any scraping necessary should be done with a safety-razor blade laid as flat as possible on the glass. Coins should not be used for the purpose.

(5) Plumbing and Water Supplies

Until the completion of the building, plumbing fittings should be looked after carefully. They can easily be broken, the glaze can be scratched by mortar and other materials and dripping taps can cause stains difficult to remove.

Where possible, access should be denied to workmen and unauthorised persons to bathrooms, w.cs. and kitchens.

In unfinished buildings water pipes may be exposed to frost, and where the water is already laid on, these should be insulated temporarily by rough lagging. A burst pipe in an empty building may remain undetected until much damage is done.

As a general rule, and especially during frosty weather, periodic inspections of all parts of buildings should be made to prevent or detect occurrences which may result in damage.

(6) Drains

It is almost impossible to prevent drains being used while the building is occupied by workmen, but as far as possible this should be done, or builder's rubbish may be allowed to enter the drains and cause obstructions after the building is occupied. Outside gulleys should be covered where possible to prevent the entry of soil or rubbish.

(7) Roofs

Tiles, slates or other roofing materials may receive damage from plumbers or others working on the roof after it is complete. Such damage may be difficult to detect and give rise to leakage at a later date. A careful inspection should be made to discover cracked and misplaced roofing units on completion of the roofing and roof plumbing.

(8) Finishings

The last work in a building usually consists of decoration and the laying of special floor finishes. Either trade may be a cause of

damage to the work of the other, especially if completion is a matter of urgency and both trades are working in the same part of the building. The best solution to the problem is to have the floor finishes laid first and properly protect them while the decorators apply the last coats. A wise precaution is to require the decorators to work in slippers when they apply the finishing coats.

Part III

SPECIAL NOTES

1. Damp-Proof Courses

Materials used for normal horizontal damp-proof courses, i.e. those used to prevent damp rising from the soil, should comply with the requirements of British Standards.

The functions of damp-proof courses are, however, varied and it is not always safe to use the materials specified in all circumstances. A choice must be made after consideration of the conditions prevailing in a particular case.

(1) Normal Horizontal Damp-proof Courses in Solid Walls

Generally, the damp-proof course used in external walls just above ground-level can be safely constructed of any of the materials specified. It is, however, necessary to use a flexible material when any danger of settlement exists. For instance, on clay soils or in mining districts, metal or bitumen damp-proof courses are to be preferred to slates set in cement or to other brittle materials.

Most local bylaws specify a minimum height for damp-proof courses above ground-level to prevent the splashing of rain on the walls above it and to avoid the risk of garden soil being piled against the wall and causing dampness. The risk of splashing is accentuated when the walls are bounded by paving, and in such cases the damp-proof course should be at least 9 in. higher than the ground.

(2) Horizontal Damp-proof Courses in Cavity Walls

In solid walls the function of the damp-proof course near ground-level is solely to prevent the rise of ground moisture by capillary forces. With cavity walls the problem is, however, more complicated, since not only is there a danger of the rise of ground water, but moisture penetrating the external leaf of the cavity or condensing in the cavity tends to flow downwards and, if a continuous horizontal damp-proof course is provided through the thickness of a cavity wall, it is likely that some of the water will flow inwards and cause dampness.

There are two common methods of overcoming this difficulty.

(*a*) A continuous flexible course can be provided which is at least one course of brickwork higher in the internal than in the external leaf. With this construction, open vertical joints should be left in the outside leaf of the wall immediately above the damp-proof course at frequent intervals, to provide drainage for the cavity, and steps should be taken to ensure that no mortar droppings collect on the damp-proof course.

(*b*) Possibly the safer plan is to provide separate damp-proof courses in the two leaves of the wall, the inner course being set one course of brickwork above the other. With this construction the cavity should be continued below the lower damp-proof course for at least two courses. When the cavity extends below the damp-proof course, it should not be allowed to serve as a receptacle for mortar droppings and other rubbish, but should be carefully cleaned on completion of the walls. Drainage holes should be provided to prevent a collection of water.

(3) Rendering over a Damp-proof Course

When a wall is rendered externally, the rendering should not be continued across the damp-proof course. Such construction may result in water being drawn from the soil between the wall and the rendering or through the undercoats of the latter around the edge of the damp-proof course, thus leading to dampness in solid walls and to deterioration of the rendering by frost or sulphate attack.

Renderings finished immediately above a damp-proof course should be thickened and throated ("bellcast") to throw water clear of the joint containing the damp-proof course.

(4) Damp-proof Courses to Parapet Wall and Chimneys

Damp-proof courses are used in parapet walls and chimneys to prevent a downward flow of moisture. In such cases the material used should be impervious and the joints should be waterproof. Bitumen felt, metal, or asphalt are all suitable materials for this purpose.

If lapped and jointed materials are used, e.g. two courses of slates in cement mortar, a good lap and workmanship of a high standard are necessary.

With solid parapet walls, a horizontal damp-proof course should be provided, continuous with or flashed over the upstand of the roofing material. It should continue through the whole

thickness of the wall, and if the latter is rendered it should form or be connected to a flashing over the edge of the rendering.

Continuous exposure of parapet walls and chimneys may lead to a saturation of the masonry above the damp-proof course, in which case water will tend to flow across the edges of the course and make the lower masonry excessively wet. If metal or bitumen felt is used, the edges can be allowed to project sufficiently to throw any water flowing from the upper masonry clear of the joint containing the damp-proof course.

A sloped damp-proof course is necessary in parapet walls of cavity construction. It should be sloped to drain inwards and the bottom edge should form a flashing over the upstand of the roofing material. Open vertical joints to drain the cavity should be left above the damp-proof course on the inner leaf of the cavity. If the wall is rendered externally, the edge of the course should extend through the rendering to form a flashing.

(5) Damp-proof Courses Under Copings

Unless a parapet coping is continuous and truly impervious to moisture penetration, a damp-proof course in addition to that suggested above should be provided immediately below the coping.

Stone, precast concrete, brick and tile jointed in mortar, are all liable to move with differences in moisture content and temperature, with the result that the joints tend to crack and permit moisture penetration into the body of the wall. This may give rise to disintegration and distortion of the parapet wall as a result of frost or sulphate action.

Since cast-in-situ concrete is liable to develop cracks as a result of drying shrinkage, a damp-proof course should also be provided under copings of this material.

(6) Damp-proof Courses Over Openings in Cavity Walls

Except in fully protected positions such as beneath deep eaves, sloped damp-proof courses are necessary in cavity walls at all points where the cavity is bridged in a horizontal direction, i.e. over all openings including those accommodating ventilators, ducts, etc., and also where floor or roof slabs are carried across the cavity.

The courses should be sloped outwards, the inner level being at least one course of brickwork above the outer. Weep holes should be provided above the course in the outer leaf.

All damp-proof courses over openings should preferably be jointless, but where their length precludes this, simple lapped joints should not be permitted. When bitumen felt is used, a good lap should be provided and the joints sealed with bitumen. The joints in metal courses should be made watertight by welting or by lapping and sealing with bitumen.

Care should be taken to see that no damp-proof course is cracked, torn or perforated during fixing or subsequently.

(7) Damp-proof Courses under Sills

Where jointed window-sills are used, damp-proof courses should be provided below them to prevent leakage through the joints to the masonry below. This applies to solid and cavity walls alike.

(8) Vertical Damp-proof Courses

Vertical damp-proof courses are necessary where hollow floors abut on solid floors and at the window and door jambs in cavity walls. A double course of slates set in cement or an asphalt damp-proof course are satisfactory for the first. For the second, bitumen felt is suitable, but slate in cement, metal or asphalt can be used.

(9) Asphalt Damp-proof Courses

The laying of asphalt damp-proof courses should be entrusted to specialist firms who are best able to advise upon the grade of material most suitable for the purpose.

For the sake of appearance asphalt damp-proof courses are sometimes not carried through the full width of the wall. This may in some cases give rise to moisture penetration and may result in uneven settlement of the wall. Serious cracking of the masonry may occur, and if the external joint is pointed in cement mortar, spalling of the facing bricks may be caused by differential loading.

(10) Lead Damp-Proof Courses

Lead is an eminently suitable material for damp-proof courses, provided it is not placed where corrosion is likely to occur or, if it is so placed, it is protected against corrosion. Lead is liable to corrosive attack by mortars containing free lime, but lime in a carbonated state is harmless. The chief danger, therefore, lies in building lead into thick walls built with a dense mortar or in concrete, for in such cases carbonation is very slow. In these situations

the metal should be protected by means of a heavy and continuous coat of bitumen.

2. Water Penetration

Most matters associated with water penetration are dealt with in other sections. A few additional notes are appended.

Many of the lessons learned by builders in former times regarding the prevention of dampness are now being neglected, with disastrous results. Then there were few truly impervious materials, little sheet metal, no modern cements and mastics, and consequently the ingenuity of the builder was severely taxed to find methods of preventing moisture penetration. A study of ancient buildings supplies much useful information on the means the old builders used to obtain dry internal walls, roofs and floors.

It is not suggested that the use of modern materials and methods of construction have not on the whole been advantageous, but in some ways there has been a retrograde tendency.

Water penetrates a building by flowing through large holes or crevices, by being forced through minor crevices and holes by wind, or by being drawn through fine cracks or porous structures by capillary forces.

The two former and to some extent the last cause of dampness are dealt with elsewhere but no mention has been made of the effect of minor details of construction in preventing dampness due to capillary action.

(1) Vertical Joints in Masonry

In all forms of masonry jointed with mortar the horizontal joints are in compression, and since the shrinkage of the building units and mortar are gradual, any slight cracks which form in such joints tend to close.

There is, however, nothing to counteract the formation of shrinkage cracks in vertical joints. These may occur in the mortar itself or between the mortar and the units, and if the mortar is stronger than the units these may crack and provide paths for moisture penetration.

Penetration therefore occurs usually through vertical joints or cracks, and if the units and mortar are both impervious, it may be more pronounced than when pervious materials are used. This is due to the greater flow of water on the wall face and the lack of absorptive properties of the sides of the cracks or joints.

Any form of bond, therefore, which increases the number or

length of vertical joints also increases the risk of penetration. Such bonds in brick masonry include brick-on-edge, brick-on-end and herringbone bond.

(2) Projecting Features

Any projecting features in masonry which suddenly check the downward flow of water tend to cause a concentration of water where the check occurs, and if joints also occur at this point, there is a danger that water will penetrate and reach the internal faces of the wall.

The joints above square horizontal breaks in wall surfaces, e.g. projecting courses of brickwork, tiles, etc., are therefore vulnerable to penetration and should be protected by a flashing.

This is especially the case when the vertical joints finishing at the projecting course are greater in number than usual, as for instance in the case of "soldier" or brick-on-end courses finishing on tile creasing or similar features.

In traditional stone masonry, joints were not made on a level with a projecting course. The stones were cut to provide a stooling.

(3) Water Concentration Under Impervious Areas

Any area of impervious material forming part of a wall face, results in concentration of water at the lower edge of the area. Thus there is more risk of penetration than normally immediately below windows, impervious external renderings, tile hanging, etc. Water flowing off such areas should be thrown clear of the more vulnerable work below by sills, drips, etc., or means such as rain-water gutters should be provided to conduct the water away.

(4) Protective Features

Among the useful features of traditional work which were originally designed to protect the horizontal walls of buildings are cornices, string courses, window labels, window-sills, etc. Designs which result in the elimination of any of these must be carefully thought out to prevent penetration.

(5) Joints of Window-Sills and Jambs

The joint between an external window-sill and the window jamb is especially vulnerable to moisture penetration. In solid walls a stooling is essential and in cavity walls the sill should not extend across the cavity, otherwise water will penetrate to the inner face of the wall either directly or by capillary action through mortar droppings collected on the sill.

(6) Window and Door Frames

On severely exposed sites water may enter between door and window frames and the wall. The joints surrounding frames built flush with the external wall surface are especially vulnerable. When frames are not set in reveals, they can usually be set back slightly without appreciably affecting appearance. The joints are less vulnerable if pointed in with a suitable mastic, e.g. linseed oil and sand instead of mortar.

In some exposed districts it is considered good practice to "tape" such joints. This consists of applying a linen tape stuck with gold-size to cover the joint and subsequently painting it at the same time as the window frame. It is claimed that this treatment is effective.

(7) External Doors

Water penetration under external doors is a great inconvenience and may be a source of dry-rot attack to floors immediately inside the doorway. Penetration can be prevented by forming the riser of the door-step flush with the door and providing an effective drip to the latter.

An automatic metal drip is available which completely covers the joint between the step and door when the latter is closed, but which rises when it is opened to clear the step. It is effective in preventing the entry of water.

In all cases door-steps should be nosed or alternatively the risers should be sloped inwards from the top edge to prevent strong winds blowing water up the riser and under the door.

(8) Projecting Horizontal Features

All flat or nearly flat projections from the vertical wall surfaces, such as hoods, cornices, etc., should be stooled and preferably flashed. If the material used in the construction of the projection is not impervious, the flashing should continue completely over the top surface and be dressed down vertically to form a drip.

(9) Cracks in Masonry

Even sound, well-built solid walls are liable to damp penetration when exposed to severe conditions of weather, but the risk is increased greatly when the masonry joints open or when the walls become cracked.

The joints may become defective by shrinkage of the mortar or walling units, crystallisation of salts in the mortar or by frost action. The remedy for the trouble is to repoint the joints. As a

general rule repointing necessitates removal of the original mortar to a depth of at least ¾ in. and renewal with a mortar which when set is rather less dense than the building unit. The joint may be struck flush with the wall surface or recessed by the use of a pointing tool of semicircular section. In the latter case the tool should be used after the mortar has hardened slightly. This will ensure consolidation of the joint and adhesion of the mortar to the units.

Cracks may also occur through settlement or locally by reason of faulty construction. For instance, the use of wooden plugs for fixing soil and rain-water pipes sometimes gives rise to defects in masonry. The plugs when they become wet expand and may cause cracking sufficiently serious to result in dampness internally. The cracks should be filled with mortar of a similar density to that of the walling units.

3. CONDENSATION

Damp walls, ceilings and floors cause serious inconvenience in a building, and may be injurious to the health of the occupants. In addition, dampness may damage decorations, plastering, floor finishes, etc., and thereby increase maintenance costs.

Condensation must not be confused with dampness due to the penetration of moisture from the outside, nor with that caused by the normal drying out of a new building. Moisture which condenses on internal surfaces is derived from the internal air.

(1) Causes of Condensation

The principles governing the deposit of condensation are simple. Air at all temperatures absorbs moisture, but the higher its temperature, the more moisture it can retain. Provided there is an ample supply of moisture, air at any temperature will ultimately reach a state when it cannot absorb any more, and it is then said to have reached saturation point.

The slightest fall in the temperature of saturated air results in a deposit of moisture, but warm air which is not saturated may still deposit moisture if its temperature is sufficiently reduced by contact with a cold surface.

The temperature of the air at which moisture condenses is known as its "dewpoint."

On hot days air in the open is warmed and absorbs moisture. If during the night the earth cools appreciably, as it always does on clear nights, the temperature of the air near the ground may

fall below the dewpoint, and moisture will then be deposited as dew. Similarly, if the warm air inside a building which has absorbed moisture given off by the occupants, or by cooking, etc., is then cooled by contact with cold walls, floors or ceilings, condensation is deposited on the cold surfaces.

(2) Temporary and Permanent Condensation

Condensation on the internal surfaces of buildings can occur under two distinct sets of conditions. First, weather conditions or lack of heating may cause the walls, ceilings or other parts of the structure to become cold. If a sudden change in the weather then occurs, resulting in warm moist air being brought into contact with the cold surfaces of the structure, condensation will be deposited. This will last only so long as the surfaces remain colder than the air. Thus a return to drier or colder atmospheric conditions or an increase in the temperature of the structure will result in the disappearance of the condensed moisture.

The more massive the walls and other parts of the building, etc., are constructed, the longer it will take for them to become warm, in response to a rise in the outside temperature, and the period during which condensation can occur will be correspondingly longer.

This type of condensation is known as "temporary condensation" because it only persists over the relatively short period of time taken by the temperature of the building to become adjusted to a rise in temperature of the outside air.

Secondly, if the walls or other parts of the structure are so constructed that they permit a rapid loss of heat from the building during cold weather, their internal surfaces will tend to remain colder than the internal air and consequently liable to condensation. Since this surface coldness may persist over long periods during the winter, the continuous deposit of moisture resulting is known as "permanent condensation."

(3) Prevention of Permanent Condensation

The remedies for permanent condensation are, to a large extent, in the hands of the designer of the building.

They include the provision of adequate means of heating and ventilation, and also the correct design of elements of the building, such as walls, ground floors, roof, etc., to decrease the rate of heat loss. However, in certain ways careful supervision can also

assist in preventing the trouble. Suggestions with this end in view are made in the following notes.

(4) Drying out of Buildings

Since wet materials permit the transmission of heat more rapidly than those which are relatively dry, a new building of conventional construction is more liable to condensation than after it has become dry. It is important, therefore, to dry a building as thoroughly as possible before handing it over for tenancy.

If the weather is dry, and especially when it is also warm, a new building should be fully ventilated, doors and windows being opened to the fullest extent to permit a through draught. This natural way of drying a building is probably the most effective, but weather conditions are not always favourable for such treatment, and artificial means frequently have to be employed.

(5) Artificial Drying of Buildings

To produce good drying conditions both heat and ventilation are necessary. Neither is adequate without the other.

It is therefore useless to raise the temperature of the inside of a building by means of fires or central heating unless ventilation is also provided.

Obviously, if weather conditions render artificial heat necessary, continual or excessive ventilation from the open air would largely nullify the effect of the heat provided. The best procedure to adopt is to close all external doors and windows until the internal air is thoroughly warm, next reopen the windows and thoroughly ventilate the building. Then repeat this sequence of heating and ventilation as many times as practicable or until drying is complete. As explained earlier, air in the process of being heated will absorb relatively large amounts of moisture, but eventually becomes saturated and so useless for the purpose of drying. More cold air must then be admitted by ventilation if the drying process is to continue.

During humid weather conditions, ventilation without heat may even retard drying.

For drying purposes, all forms of heating which produce large quantities of water vapour should be avoided. Oil and gas-burning appliances, unless equipped with vents discharging into the open air, are unsuitable for the purpose. Central heating by hot water and electric heating are the most satisfactory methods.

(6) Effect of Moisture on Insulating Materials

Insulating materials are effective only because of their low density, which is usually due to their structure being of a cellular nature.

If they become wet the air cavities take up water and the resistance of the material to heat transmission is reduced. All insulating materials should therefore be protected against moisture before they are used and also after they are in position in a building.

In this connexion it is to be noted that insulating materials can absorb moisture from the air inside a building as well as from external sources.

With certain forms of construction this point is of great importance. The two following examples will serve as illustrations. In one instance a building with concrete walls was lined internally with cork, one of the best forms of thermal insulation available. For a year or two the construction was effective, but subsequently, condensation occurred upon the wall surfaces. On examination the cork was found to be saturated with water, and consequently its effectiveness as an insulator had been lost. The cause of the trouble was that the moist air inside the building had percolated through the cork and condensed at the inside surface of the concrete wall. In the course of time the quantity of condensed moisture was sufficient to saturate the cork.

In another instance a roof, which was almost flat, was covered with steel sheets and a layer of mineral wool was laid upon the upper surface of the first-floor ceiling to reduce heat loss. In cold weather a heavy deposit of condensation, at times in the form of hoar-frost, formed on the under side of the roof sheets. Dripping of water from the roof sheeting was so serious that the mineral wool became saturated and water penetrated through the ceiling into the rooms.

A consideration of these instances at first suggests that if the moist air from the inside of a building can be prevented from reaching a cold surface, no trouble can occur. This is, however, only true when no cavity exists between the inside linings and the outside surfaces of a building or the cavity is completely sealed. In the latter case only a small quantity of moisture originally present in the air in the cavity is available, and any deposit of moisture must necessarily be small in quantity, even when conditions are most conducive to condensation. If, on the other

hand, the cavity is open to the external air, an unlimited supply of moisture brought in by relays of air is available. During clear nights a horizontal surface, such as a roof, radiates heat rapidly to the sky and its temperature may therefore fall considerably below that of the air in contact with it. Condensation may then occur on its exterior surface, and if the roof membrane is composed of material of high thermal conductivity, on the interior surface also.

The remedies for the trouble are therefore: either to prevent air from both the interior and exterior of the building from reaching the cold inner surfaces of walls and roofs. This can be achieved by providing vapour-proof membranes, e.g. metal foil, bitumen felt, etc., with sealed joints on the room side of the insulation and sealing any cavity which may occur between the insulation and the wall and roof cladding. Alternatively, in the case of roofs, it becomes necessary to ventilate the roof space and to provide adequate insulation above the roof covering to prevent it from becoming cold. This, of course, entails the provision of a waterproof membrane above the insulation.

Similar principles are involved in preventing condensation under valley gutters in factory premises, etc.

(7) Palliatives for Condensation

In certain circumstances the internal surfaces of a building may be subject to condensation for relatively short periods. Conditions favourable for this are when the temperature and humidity of the inside air are suddenly raised, e.g. during cooking or washing operations, and when the wall or ceiling linings are of material having low absorptive properties.

In such instances condensation, though occasional, may occur for sufficiently long periods to become a source of annoyance; water may drip from the ceiling or run down the walls.

Provided such conditions are only of brief duration, the trouble can be overcome by providing absorbent surfaces such as reasonably soft plastering or a sprayed asbestos treatment, which will retain the moisture until conditions are favourable for drying. The absorptive properties of the treatment must not, of course, be spoilt by the application of enamel or glazed paints.

Alternatively, granulated cork can be sprayed or hand applied to a suitable paint base. This provides some insulation and a

rough texture which, being capable of holding a certain amount of water, prevents dripping for a while.

The methods suggested cannot be considered to be a cure for permanent condensation unless the applied treatments are sufficiently thick to provide an appreciable amount of thermal insulation. They are effective only so long as the moisture deposited is insufficient to saturate the absorbent treatments or to overload the textured finish.

4. Unsafe Admixtures of Building Materials

Serious troubles can arise as a result of mixing together certain building materials.

Materials which may cause such trouble may be added to mortars, paints, etc., by mistake or sometimes by design, to render the operative's work less difficult. Some of the more common troubles arising from this cause are dealt with below.

(1) Portland Cement and Unsound Lime

In many parts of the country the mixing together of lime and cement is looked upon with suspicion, it being considered that the two materials are incompatible. This is only true when unsound lime is used.

The result of mixing unsound lime with cement, which has a relatively fast set, is that the mortar or plastering mix hardens rapidly and the unslaked particles of lime are tightly bound in the set mortar. Under damp conditions these particles eventually become slaked, expand, and cause local "blowing," or if they are numerous and uniformly distributed, general expansion of the mortar. Distortion and disintegration of the masonry or plastering in which the mortar is used then occurs.

As discussed under "Internal Plastering," eminently hydraulic and magnesian limes contain slow slaking constituents, and it is desirable, therefore, not to mix them with cement unless the most scrupulous attention is given to the slaking process.

Both types of lime can, if properly slaked and used, provide a suitable mortar for certain purposes and the addition of cement is therefore unnecessary.

Properly slaked fat limes or greystone limes are useful admixtures to cement mortar, when a less dense or more workable material is required.

(2) Gypsum Plasters and Portland Cement

No plaster (calcium sulphate plaster) should in any circum-

stance be included in a mix containing cement. Chemical reaction may take place between the two materials resulting in the formation of sulpho-aluminates. The effect is that the mix either never attains proper strength, or if after setting hard it becomes damp, it tends first to expand and then to disintegrate.

The addition of plaster to a cement mortar used for rendering makes the mix more workable and also increases its rate of set. There is a temptation, therefore, for plasterers to incorporate plaster in cement mortar, especially when mouldings are required to be run *in situ*.

The expansion following the use of plaster and Portland cement in the same mix can cause complete failure of plastering and such distortion of masonry as to necessitate rebuilding. It may even endanger life should cornices, string courses, sills, etc., split apart and fall piecemeal from a building.

(3) Plasters with Differing Properties

The mixing together of various types of plaster may result in serious variation in setting time, loss of strength, and deterioration of applied decorations.

(4) Keene's Cement and Lime

Lime additions to accelerated anhydrous plasters, e.g. Keene's cement, may adversely affect decorations.

(5) Unauthorised Mixes of Paint, etc.

Unauthorised additions to decorator's materials or the mixing together of various types of paint may also give trouble.

The supervisor should permit only such additions or mixtures as he knows to be safe and desirable.

5. Building in Frosty Weather

In this country, frost is rarely so severe or prolonged as to warrant heavy expenditure in plant to enable the work to proceed at low temperatures.

In exceptional cases it may be necessary to carry on work through a severe winter, regardless of cost of special precautions in concreting, bricklaying and plastering.

The following notes indicate the main lines of approach to the problem, which is dealt with comprehensively in "Building Research Wartime Building Bulletin No. 11," H.M. Stationery Office.

(1) Effect of Frost on Concrete and Mortar

If new concrete, mortar or plastering mixes become frozen, the set ceases and the expansion caused by the freezing of water in the mix may be sufficient to cause disintegration. There is no remedy for this except renewal of the damaged work.

Failure of concrete or mortars can also occur when frozen aggregate is used. There is a risk of this happening even after a thaw has commenced.

Another important effect of low temperature is to slow down considerably the rate of setting of hydraulic limes and cement. This can occur even when the temperature is not below freezing-point.

(2) Ordinary Winter Precautions

Temperature cannot be judged by guesswork, and it is therefore essential to provide suitable thermometers on every job to test the temperature of the air, aggregates, water, placed concrete and the soil. Suitable instruments are available, e.g. soil thermometers, and should be part of the equipment of those engaged in the supervision of building work.

During the winter all materials for concrete, brickwork and plastering should as far as possible be stored in positions which are reasonably dry and not subjected to extremely low temperatures.

The process of mixing mortar and concrete should also take place under similar conditions. If this is impracticable, it becomes necessary to make sure that no materials are used when their temperature is below freezing-point.

Unless special precautions are taken, concreting, bricklaying and plastering should be stopped when the air temperature is falling and has reached 38° F., and should not be recommenced until a recurrence of frost is unlikely and the temperature rises to at least 34° F.

All concrete and brickwork placed when the temperature is low should be protected by sacking, scaffold boards, etc., until all danger of freezing is over.

Before loading concrete which has been placed during a frost it is wise to ensure that it has actually set and hardened and has not become frozen. This can be done by warming it at a few points and afterwards testing its hardness.

The utmost care is necessary in stripping formwork, and

removing struts to reinforced concrete placed under cold or frosty conditions. Concrete may take twice as long (or more) in cold weather as in warm weather to gain the strength necessary for safe removal of support.

Internal plastering should only be carried out in frosty weather when it is possible to exclude draughts from a building and provide sufficient heat to keep the temperature at a reasonably high level (say above 38° F.). It is dangerous to apply external plastering if there is any risk of frost.

Concrete should never be laid on frozen ground. Placing should be delayed until the temperature has risen sufficiently to ensure a complete thaw.

(3) Building During Severe or Prolonged Frosts

To carry out concreting, brickwork or plastering during severe or prolonged frosts is a dangerous procedure and should only be done in an emergency. Then the utmost care must be taken with the work.

The precautions necessary include heating materials, water and concrete formwork before use and afterwards, protecting the placed work by screens and by providing warmth.

Bricks should be used as dry as possible and any adjustment in suction made up by using a wetter mortar made with heated ingredients, including the water.

Obviously such measures involve heavy expenditure and should only be contemplated in special cases.

Full particulars of the methods which can be used are given in the "Building Research Bulletin" to which reference is made above.

6. Thermal Movements of Roof Slabs

The horizontal surfaces of buildings are exposed to larger variations in temperature than other parts of the building.

In sunny weather their temperature may rise many degrees above the air temperature and on clear nights fall considerably below it.

All building materials expand and contract to a greater or lesser extent with variation in temperature, and with large flat concrete roofs, long lengths of coping, etc., this movement may be sufficient to cause serious cracking of walls and partitions.

Special precautions to guard against this are not usually considered necessary unless the length of the roof or coping exceeds

100 ft. Above this length the probable movement is so large that measures should be adopted to avoid damage.

The problem can be approached in two ways, either by providing thermal insulation to reduce the variation in temperature or by the provision of expansion joints.

Roof slabs can be insulated by means of cork, wood fibreboard, lightweight concrete, etc., laid between the slab and the roof covering, or a reflecting surface such as limewash can be applied periodically.

Expansion joints may consist of compressible material, e.g. bitumen, or of flexible metal strips. Where expansion joints are provided, means to permit some movement of a roof slab relative to the structure is necessary. Seating the slab upon a double layer of thin sheet copper with a graphite treatment between the layers has been suggested for this purpose. The seating should be used wherever the slab bears upon other parts of the building.

7. Wall Ventilators

(1) Effective Ventilating Area

Wall ventilators are frequently specified by overall size, regardless of the actual ventilating space provided. This may result in the use of ventilators of inefficient design, and consequently to the inadequate ventilation of rooms and floor spaces.

Square-mesh metal ventilators may have effective ventilating area as much as 40 per cent. of the total area; but with some terra-cotta air-bricks the ventilation provided may be almost negligible.

Where for the sake of appearance or for other reasons it is thought desirable that air-bricks of lower efficiency should be used, the number of ventilators should be increased to make up for the deficiency in actual ventilating area.

(2) Water Penetration Through Wall Ventilators

Although wall ventilators are small in area, openings for their accommodation in walls must be treated in the same way as larger openings.

Water entering the inlet face of the ventilator may penetrate into the wall beneath, or, in cavity walls especially, penetration may occur over the top.

Connexions between the external and internal air grids should therefore be waterproof, and in cavity walls sloped gutters should be provided above the openings.

(3) Vermin Infestation

Insects, mice and small birds are able to pass through many types of external ventilators. As far as possible this should be guarded against by protecting the back of the outside air grid with copper gauze of suitable mesh.

(4) Ventilators to Cavity Walls

Ventilators in cavity walls should not be used for dual purposes. If it is required to ventilate the cavity, no inlet to the inside of the house should be provided. If, on the other hand, ventilation is required to rooms or to the under-floor space, the inner and outer air grids should be connected together with a "sleeve" of impervious material.

(5) Ventilators to Rooms Without Fireplaces

Most bylaws require rooms without open fireplaces to be provided with ventilators. The object of the bylaw is nullified if it is possible to prevent the ingress of air through the ventilator. For instance, adjustable ventilators fixed on the interior of walls enable tenants to close them permanently to exclude draught.

The omission of the interior grating permits a partial closing of the ventilator by the use of the shelf formed in the thickness of the wall as a receptacle for books or other objects.

8. Pattern Staining

Disfiguration of the internal surface of a building may occur by the differential deposition of dust. Common examples of the trouble are, the darkening of the plastered surface of the reinforced concrete in hollow tile and concrete roof slabs and the appearance of dark areas over the heads of nails used for fixing ceiling or wall boards.

The cause of the trouble is that dust collects more easily on cold surfaces than on those which are warm. If, therefore, any form of thermal insulation provided, e.g. an air cavity or a layer of insulating material, is not continuous, dust is likely to collect over those parts of the structure which are less well insulated.

In design, it is important to ensure that the same or nearly the same amount of thermal insulation is provided at all points in the walls or in other parts of a building, and the supervisor should carefully inspect the fixing of materials used for the purposes of insulation to ensure continuity.

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